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IMPLICATIONS OF THE BUDGETING PROCESS ON STATE-OF-THE-ART (SOA) EXTENSIONS

by

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Implications of the Budgeting Process on State-of-the- Art (SOA) Extensions

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ABSTRACT

This thesis is a case study which compares the estimated and actual costs of a weapon system which experienced a state-of-the-art (SOA) extension. The subject of this case study is the primary electromagnetic warfare support measures system on 637 class submarines. The system is produced by GTE Government Systems Corporation. This study analyzes the corporation's budgeting process and two production contracts to determine whether either contributed to the costs associated with SOA advance. The budgeting process did not appear to have any significant affect and the variance analysis of the contracts indicated that cost estimating uncertainty increases in SOA advance situations, particularly in the development and initial production phases. It appears cost estimating accuracy improves as a program matures into production.

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I. INTRODUCTION

A. BACKGROUND

State of the art (SOA) advancement is commonly required for development of sophisticated electronic weapon systems. The cost of SOA extensions is difficult to accurately estimate. As a result, the initial estimates of development and early production costs frequently contain significant error. This is due to our lack of understanding of the relationship between various levels of SOA advancement and development and initial production costs.

The Naval Sea Systems Command (NAVSEA) has suggested that there may be an association between levels of SOA extension and cost overruns. Such cost overruns cannot be tolerated in the fiscally constrained environment currently facing the Department of Defense (DOD). Budgets must accurately reflect actual expenditures to permit efficient and effective management of scarce defense dollars. NAVSEA must often decide between procuring weapon systems that fall within existing technology or pursuing SOA advancement to upgrade a particular weapons system. Costs associated with existing technology are obviously much easier to estimate because historical data exist. SOA advancement cost is more difficult to accurately estimate prior to project initiation.

NAVSEA has requested assistance in developing a reliable methodology for accurately estimating the costs of advancing technology in electronic weapon system components. With the subject of methodology, NAVSEA hopes to be able to better project weapon system expenditures, which will significantly contribute toward more reliable and accurate budgeting.

Accurate cost projection is essential to proper management of limited defense dollars. In addition, Congress and its numerous committees closely scrutinize defense spending all the way from the budget formation stages through actual budget execution. The DOD must be as accurate as possible to maintain credibility, and to receive their fair share of the Presidential Budget and budget appropriations from Congress.

The most logical approach to solving the problem of inaccurately projecting the cost of SOA extensions is to develop a parametric model that will assist users in estimating the associated costs. This thesis is one of four case studies which will detail actual SOA extensions in weapon related electronics. The objective of the case studies is to determine whether current knowledge from related disciplines can be used to establish quantifiable relationships between SOA advancement and development and production costs. These relationships will then be used in developing a parametric model to assist in estimating the cost of SOA extensions.

This particular case study focuses on the interaction between the budgeting process and accurate estimation of development and initial production costs associated with SOA extensions. It is being conducted in conjunction with the Tactical Electronics Defense Division of GTE Government Systems Corporation. The specific weapon system which is analyzed in this case study is the AN/WLQ-4 Sea Nymph, a multimillion dollar electromagnetic warfare support measures (ESM) system, manufactured for the Navy by GTE Government Systems Corporation. This particular ESM system is currently employed in the fleet today aboard 637 class fast attack submarines (SSN). It represents an improvement or SOA extension over its predecessor, the AN/WLR-6 ESM system.

B. RESEARCH QUESTION

The primary focus of this research is to compare projected development and initial production costs with the costs which were actually incurred in the development and production of the AN/WLQ-4 Sea Nymph. Conclusions are drawn to explain the reasons behind any differences between actual and estimated costs. Particular emphasis will be directed toward GTE Government Systems Corporation's budgeting process, as it relates to SOA extensions. This process will be analyzed to determine if budgeting procedures play a role in any cost overruns associated with the development of the AN/WLQ-4 Sea Nymph. The primary research question is: Does GTE Government Systems Corporation's internal budgeting process contribute to the differences between estimated development and initial production costs and the costs which were actually incurred in these areas? Subsidiary research questions relate directed to the following areas:

- General corporate policy for Independent Research and Development (I R and D).
- Identification of key participants and an analysis of the interaction between the key participants engaged in the budgeting process.
- Tracing the AN/WLQ-4 Sea Nymph through the budgeting process.
- Ability of the budgeting process to successfully estimate costs.

Primary and subsidiary research questions were answered through a case study methodology. This included interviews with personnel involved in manufacturing, program management, cost estimation and analysis, accounting, and budgeting. Extensive cost data were also obtained which reflected the effort to develop, prototype, and manufacture the AN/WLQ-4 Sea Nymph. The original estimates for these costs were also obtained. In addition to the focus on the role of the budgetary process in the development of the Sea Nymph, this study includes an analysis of significant differences between actual and estimated costs in the development and initial production areas. This is seen as a crucial subsidiary research question.

C. SCOPE, LIMITATIONS, AND ASSUMPTIONS

The AN/WLQ-4 Sea Nymph represents an upgrade or SOA extension over the AN/WLR-6 ESM system. Development of the Sea Nymph began in 1974 and initial production of a prototype began in 1976. The installation phase of the program began in 1979 with USS Bergall (SSN-667). Production of the final unit was completed in early 1987 and is scheduled for installation on USS Sunfish (SSN-648) in August 1988. GTE Government Systems Corporation produced a total of 43 Sea Nymph units which are installed or designated for installation on fast attack submarines (SSN). These 43 units are referred to as E suites. In addition, Government contracts also called for the production of 20 portable systems which could be interchanged among operational SSNs which already had E suites installed on board. This insured that at sea or underway, SSNs could have both suites, giving each boat additional operator stations and increased capability. The 20 portable units are referred to as N suites. To put the units in some perspective, one E suite is the equivalent to 4 N suites in terms of relative price. In summary, the Navy awarded GTE Government Systems Corporation eight contracts which included the development through final production of both the N and E suites. The following is a brief capsulation of the contracts involved in the Sea Nymph program:

- Engineering Development Model (EDM). A cost plus award fee/cost plus fixed fee contract which called for the development of one N suite and one E suite.
- Interim Development (ID). A cost plus award fee contract which funded additional development work on the original N and E suite models.
- Limited Production (LP). A cost plus award fee contract which called for the production of five E suites and four N suites. The quantities included the development models.
- Pilot Production I. A cost plus award fee contract which called for the production of eight E suites and three N suites.
- Pilot Production II. A cost plus award fee contract which called for the production of six E suites and zero N suites.
- Pilot Production III. A cost plus award fee contract which called for the production of five E suites and one N suite.

- Production I. A firm fixed price with incentive fee contract which called for the production of ten E suites and six N suites.
- Production II. A firm fixed price with incentive fee contract which called for the production of nine E suites and six N suites.

This case study concentrates primarily on the Production I and Production II contracts. These contracts were the latest in the Sea Nymph Program and subject to the Cost/Schedules Control Systems Criteria which the DOD instituted in June 1977 with the promulgation of DOD Instruction 7000.2. Several external factors impacted the early development and pilot production contracts and rendered their utility to this study impractical. First, the costs were heavily influenced and increased by the Navy's requests for expedited development and delivery. Secondly, the operational schedule of the submarines caused the original Sea Nymph installation schedule to change. This resulted in modification to the production requirements and ultimately resulted in increased costs. Thirdly, there was a carry over of technical problems from EDM to ID to LP which makes the identification of specific problems to specific costs impossible. As a result associated variance analysis is misleading and inaccurate. Finally, the Navy submitted numerous engineering change proposals (ECP) and the system experienced many combination changes all the way through Pilot Production III. Many units designated for fleet use were produced during the development process. This makes the actual separation of development and production costs difficult as some development money was used to fund units which would normally be associated with procurement funding. For these reasons, the final two production contracts possess the most realistic, quantifiable, and discernable program cost data. Also, these contracts do not overlap each other or any other contracts, as is the case with several of the earlier development and pilot production contracts.

Another factor which deserves mention is the role of subcontractors in this program. GTE Government Systems Corporation is the prime contractor. The subcontractors

include corporations such as IBM, Genisco, Almond, Microphase, and Langely. (See appendix A for a complete listing.)

GTE Government Systems Corporation has three primary functions as the prime contractor in the production of the system. First, they function as a system house responsible for compatibility and inter-operability of the numerous subcontracted components of the system. Second, they are the system integrators whose primary concern is the functional capability of the system on board the submarine platform. This includes the installation of the system and ensuring integration with other installed equipments. Third, GTE Government Systems Corporation is responsible for all the system cabling. This includes cabling between the various system components, and between the overall system and the submarine.

As evidenced by the use of subcontractors, it was not necessary for GTE Government Systems Corporation to perform the research and development for all the Sea Nymph subsystems. They were able to upgrade the AN/WLR-6 system and advance the SOA for this ESM system by incorporating technological improvements into the development of the Sea Nymph. This was accomplished by improving several components of the system in addition to simply adding equipment and expanding the overall capability of the system. SOA has been advanced in a manner particular to this ESM system. GTE Government Systems estimates that ESM capability was increased by over 100% in the transition from the AN/WLR-6 to the AN/WLQ-4. (Ref. 1).

SOA is seldom precisely defined.

> Its meaning typically falls somewhere between (1) the best that has been accomplished, and (2) the best that could have been accomplished (but may not have been for budgetary or other nontechnical reasons). (Ref. 2:p. 130).

The former definition is used in this study as SOA measurement is predicated on what has actually been accomplished as opposed to what could have been accomplished.

D. METHODOLOGY

> Methodology is defined as the particular set of strategies, domains, and techniques employed in generating or testing theory. (Ref. 3: p. 23).

This study is, in broad terms, a combination of basic and applied research. It is a basic research in the sense that new information or knowledge is sought concerning cost estimation for SOA extensions and the role of the budgeting process. It is applied research in the sense that basic principles and existing knowledge are applied toward the solution of a problem, specifically, how costs associated with SOA advancements can better be estimated and controlled. The new information which is ultimately being sought is a parametric cost model which will help estimate development and initial production costs for systems which represent an SOA extension. However, this study tends to be more applied than basic because of the focus on the role of budgeting.

The initial steps, after defining the direction of the study, was to identify a corporation which would serve as a subject for case study. The marketing directors and research and development (R and D) managers of numerous electronics corporations were contacted and introductory meetings were scheduled. A meeting with GTE Government Systems Corporation was conducted on 23 July 1987. It was at this time that they agreed to participate in the study, and the AN/WLQ-4 Sea Nymph ESM System was tentatively chosen as the electronic component/system whose costs would be measured. The Sea Nymph System was later confirmed as the subject and portions of this program are used as data in this study. The Sea Nymph program is also the point of reference for many conversations and interviews with various members of the GTE Government Systems Corporation.

The Sea Nymph case study, as a form of empirical research, attempted to focus on behavior rather than opinion but, due to the nature of SOA advancement and the limited amount of research in the area, expert opinion is used as an information source and as an

aid to data interpretation and analysis. With the domain of the research established, formal data which are taken primarily from cost performance reports and performance data worksheets. However, reports were not readily available from the early development phases of the program because the Cost/Schedule Control Systems Criteria (C/SCSC) had not been implemented and archival records could not produce all the necessary data. The subject reports and data were much more accessible following the implementation of C/SCSC with DODINST 7000.2.

A description of the Sea Nymph Program was obtained from two sources: the current program manager, Shirley Chow, and Stanley Swales, the program's lead cost analyst. Mr. Swales had particularly keen insight into total program costs because he used Sea Nymph as the historical data source for establishing cost estimating relationships needed to develop a parametric cost estimating model for GTE Government Systems Corporation's Western Division. These two individuals provided information and answered questions relating to virtually every aspect of this case. Individuals from the Management Control Systems Training and Audit Division, especially Helen MacLean and Steven Massey, were the primary information sources for the description of the corporations budgeting process. Internal corporate publications addressing management control systems, general policies and procedures, and cost account management were also used as information sources.

The interviews and informal discussions which provide the majority of the subject material for this case study were conducted through approximately ten visits to the GTE Government Systems Corporation plant in Mountain View, California. These visits took place between July and November 1987.

Information relating specifically to SOA advancement cost estimating was obtained through literature review and visits with Dr. Edward Dodson of General Research Corporation, Santa Barbara, California, the Cost Analysis Division at USAF Space

Division, El Segundo, California, and The Aerospace Corporation, Resource Cost Analysis Office, El Segundo, California.

The remainder of this study is presented in accordance with the following outline:

Chapter Two. This chapter serves as background and discusses several relevant disciplines and concepts which have contributed to the field of SOA measurement and technological advance. This section also includes a discussion of applicable budgeting concepts which affected GTE Government Systems Corporation's planning and control efforts during the Sea Nymph Program.

Chapter Three. This chapter presents the product of the case study and the actual data. The data presentation includes a comparison of the budgeted and actual costs incurred in the Production I and II contracts of the Sea Nymph Program. A description of the corporation's overall budgeting process and its role in the management control system is also included in this chapter.

Chapter Four. This chapter analyzes the data presented in Chapter Three by specifically interpreting the variances between budgeted and actual costs.

Chapter Five. Conclusions and recommendations are presented at this point. Conclusions include the relationship between the budgeting process and the SOA advance depicted in the Sea Nymph Program, and a discussion of the effectiveness of the budgeting process in controlling costs during the Production I and II contracts.

II. BACKGROUND

A. INTRODUCTION

Many disciplines and subjects have a relevant and general influence on the budgeting process and its effect on SOA advancement cost estimating. These disciplines include general fields such as cost estimating, corporate budgeting, SOA measurement, and weapon system acquisition. This chapter discusses the background theory and procedures from several related fields which are applicable to the study of the SOA advancement cost estimating and the role of the budgeting process.

B. COST ESTIMATING

1. General

The cost estimate is an integral component of the weapon system acquisition and budgeting process.

> The estimate and the budget it supports is the traditional yardstick by which program afforability, progress, and success are measured. (Ref. 4:p. 1-1)

Accurate cost estimates and reliable budgets are requirements for well managed acquisition programs.

High quality cost estimates must be available to decision makers at the Congressional, Secretary of Defense, Secretary of the Navy, and program management levels.

> Cost estimates for major weapon systems are a crucial part of the acquisition process, especially in a resource scarce environment. If decision makers are to exercise sound judgement about the afforability of weapon systems, high quality estimates of weapon systems' costs must be generated by DOD and the services. (Ref. 5:p. 1)

2. Purpose

Cost estimating is defined by the National Estimating Society as the art of approximating the probable work or cost of something based on information available at the time (Ref. 4:p. 2-7). Other definitions of cost estimating exist, but cost estimates are generally used in two ways: comparative studies and budget formulation. Comparative studies permit selection among alternatives that are available to satisfy a particular requirement. Budget formulation provides support and justification for the budget process by estimating what will be required to effectively carry out a project or program. These two general uses can be more precisely defined to fulfil more specific uses to support program change and funding level decisions, program reviews independent of advocacy, procurement procedures, major program decision points, and economic analysis (Ref. 4:p. 4-2). Many of these specific uses have been given formal titles and descriptions in the DOD weapon systems acquisition process. Regardless of the cost estimate's use, the estimator should know the intended use, the level of detail, the necessary degree of accuracy, the scope, and the availability of the data on which the cost estimate will be based. Without this information, the cost estimator's effort could be mislead, his ability to achieve a quality product could be severely reduced, or the final product may not satisfy the needs of the requestor or customer.

3. Understanding the System

It is the cost estimator's responsibility to understand the purpose and characteristics of the system for which he is generating a cost estimate. Even though knowledge of the system's purpose will not provide the cost estimator with a great deal of detailed technical knowledge, the information will at least permit him to form a general idea regarding the cost and complexity of the system. A space system application, for example, requires higher reliability through design redundancy and is subjected to a much more

rigorous testing program than an airborne or ground system fulfilling a like mission. Knowing something about the system's purpose, the cost estimator is at least made aware of the extent to which he must gather additional detailed information about the system's characteristics. Through these estimates, the cost estimator is able to develop a detailed cost estimate.

4. Characteristics

Physical and performance characteristics of a weapon system are important to the cost estimator because they have a direct impact on cost. Characteristics are numerous and they vary depending on the type of system involved. Table 1 is an array of physical and performance descriptors as they apply to several types of systems (Ref. 4:p. 4-12).

Virtually all complex weapon systems possess sophisticated data processing capability and cost estimators must incorporate data processing and software estimates into their projections. Characteristics which describe the data processing components of weapon systems include: memory size, processing speed, lines of code, language employed, expansion factors, and the proficiency of the programmers.

Parametric cost estimating models employ exact non-cost parameters as inputs. These inputs function as the independent variables in the model's cost estimating relationships (CER). So it can be clearly seen that the characteristics of the system being estimated must be accurately described. When the analogous form of cost estimation is used, the cost estimator wants a comprehensive list of characteristics so he can select the strongest analogies from preceding or similar systems. (Ref. 4:p. 4-13)

For cost estimates occurring early in a system's life cycle (development and early production stages), the most important input to the estimating methodology is an extensive description of the physical and performance characteristics. Obtaining these inputs is no easy matter and presents a significant challenge to the cost estimator. He must rely on

engineers and other personnel from the program office to provide the characteristics, which are very often estimates themselves during the development and technical evaluation phases of the weapon system acquisition process.

TABLE 1

TYPICAL SYSTEM DESCRIPTORS

ELECTORNIC	AERONAUTICAL
Frequency	Mission and Profile
Operating Power	Altitude
Cooling Power	Range
Packaging	Speed
Data Rate	Size and Weight
Bit Error Rate	Material Mix
Weight and Volume	Wetted Area
Location	Load Factor
ARMAMENT	**SPACE**
Weight	Mission and Duration
Speed	Thrust
Complexity	Launch Vehicle
Range	Altitude
Target Class	Design Life and Reliability
Circular Error Probable	Orbit Type
Fuses	Pointing Accuracy
	Satellite Type
	Sensors
	Weight and Volume

5. State of Technology

Once the cost estimator identifies the purpose and physical and performance characteristics of a system, his next step is to evaluate the existing state of technology which will be incorporated in the weapon system.

> In other words, where does the new system reside in relation to the state of the art? (Ref. 4:p. 4-15)

What technology must exist in order to produce the weapon system, including all its related components? These questions are easy matters for the cost estimator if needed technology has already been developed and is readily available. Technology in this category is referred to as "off-the-shelf." Costing such items is easily accomplished with catalogs or vendor quotes and is the price normally associated with a bill of sale.

Most development programs are initiated expressly to advance the level of operational technology and the degree of technological advance is directly related to cost. Cost estimators must also understand whether the technology required for a weapon system is newly developed and represents a new or first time application, or if the technology must be developed in order to build a weapon system. Weapon systems which are built for the first time with existing SOA technology are much more tangible for the cost estimator. Parameters, and performance and physical characteristics must be estimated, but cost estimators at least have tools such as parametric or analogous methodology to develop a cost estimate. The situation becomes much more difficult when the technology required to develop a new weapon system has not yet been realized. Many cost estimators apply the same approach to undeveloped technology as they would for using current SOA technology. They make the assumption that the technology necessary to design, develop, and test the new weapon system will arrive in time to support all the phases leading to production. There is a drawback to this approach. Even though it permits the cost estimator to make an estimate, risk increases, and the potential impact on cost and schedule

could be devastating. Figure 1 is a schematic which describes the relationship between the three levels of technology (off-the-shelf, SOA, beyond SOA) and the degree of risk which must be assumed by the cost estimator as part of the estimate's risk assessment (Ref. 4:p. 4-17). Technology implications must be a critical consideration to the cost estimator because of the major impact technology availability will have on a program. Advocates of a new weapon system tend to minimize risk and fail to perform the skeptical analysis needed by decision makers to evaluate "best case" and "worst case" scenarios. As stated in a GAO report:

> Cost estimates do not always include adequate provisions for program risk. Cost estimators seem to assume that their weapon systems will not suffer from the risk factor that can occur on weapon programs. (Ref. 5:p. 25)

The impact of incorrect assumptions on cost and schedule must be clearly portrayed.

6. Configuration

So far, the purpose, characteristics, and technology impact on a weapon system have been discussed. The cost estimator must next concern himself with the configuration of the weapon system being estimated. Several configurations normally exist for a system, especially in a competitive bid environment where several potential sources exist. Assuming that the proposed configurations meet all the specifications, much variation in the systems may very well exist. Are cheap or expensive materials to be used? Will power supplies be at the upper or lower end of the spectrum which meets specified criteria? Cost estimators must understand a system's composition in order to use physical characteristics as an input for estimating cost. System configuration awareness is of paramount importance when an analogous approach to estimating is taken. The estimator must compare the configurations of the existing and the proposed system by looking at the technical parameters and characteristics. He reviews the levels of technology in both

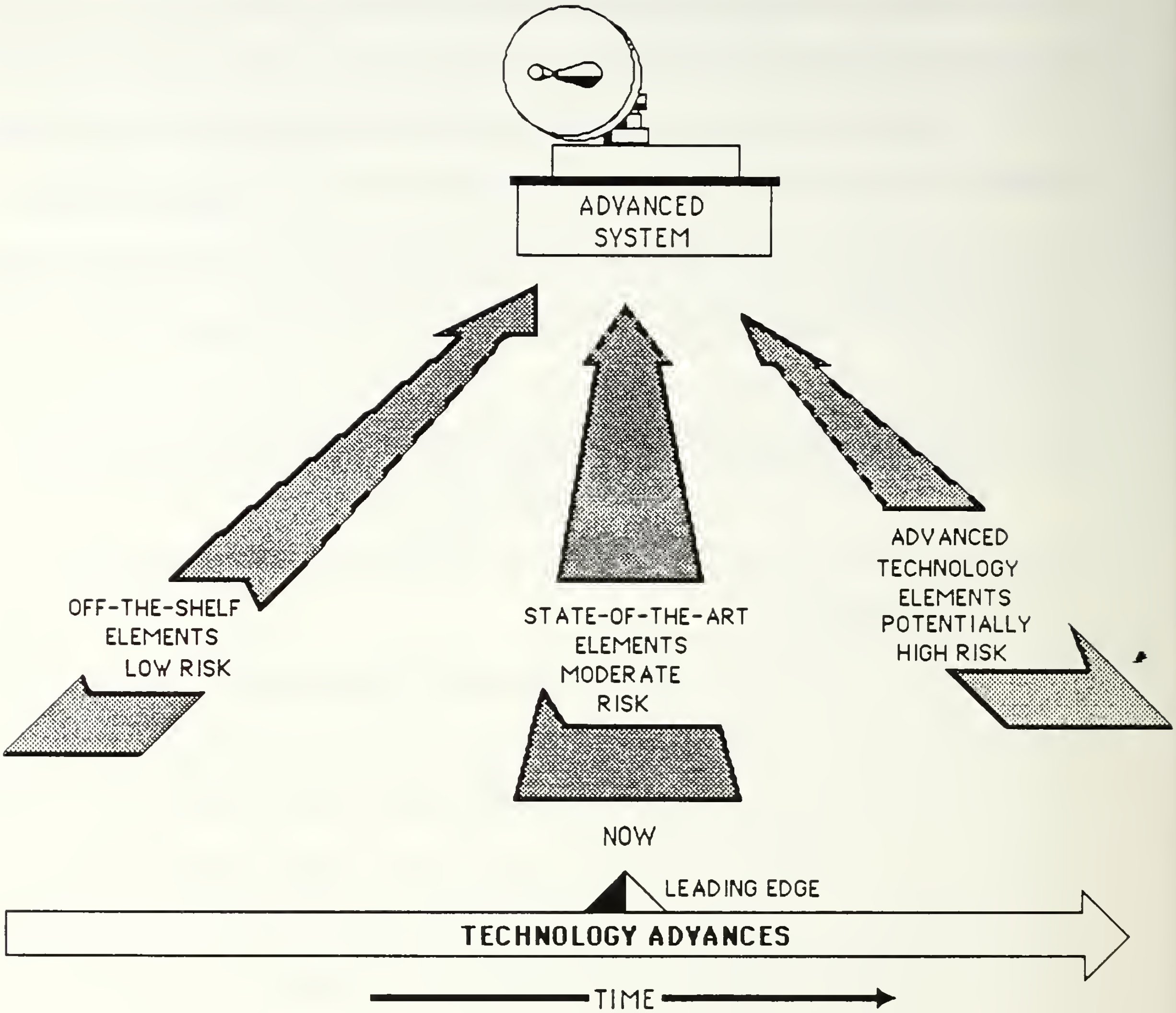


Figure 1. Technology and Risk Relationship

systems and develops cost complexity factors which are used to transform the cost of the existing system into a cost estimate for the analogous or proposed system.

7. Interrelationships of the System

Another factor the cost estimator must consider is the degree of interrelationship a new system has with other systems. The Sea Nymph provides an appropriate example. Installation of the Sea Nymph ESM system on 637 class submarines required extensive integration with the boat's power supply sources, installed equipments, and air conditioning system. If these interrelationships were not considered and the system was developed and produced in the laboratory environment, cost would be significantly understated initially. Then the cost estimator would realize his error and be faced with an expensive redesign effort. The cost estimator must have the foresight to determine how the new system is to be physically located or installed, if these are valid considerations, and how it will be integrated with its operational environment.

8. Support

Repair part and maintenance support are requirements the cost estimator should incorporate into his estimate. These factors are not discussed in much detail because they represent ownership cost rather than development and production cost, the primary focus of this study. Supportability requirements are built into a system early in the design phase and affect program acquisition cost. The degree of supportability that is designed into a system drives cost as does the determination of Government or contractor repair and maintenance responsibility. As weapon systems become more complex and sophisticated, maintenance concepts and plans also advance. Several maintenance philosophies exist. The cost implications of these different approaches vary and must be considered in detail when deriving cost estimates.

9. Schedules and Quantities

The development and production schedules, and the manufactured quantities associated with each schedule, are data the cost estimator is usually provided with. He should evaluate these quantities to determine if anything appears unrealistic. The area the cost estimator should be most suspicious of is the quantity of development and production units required to support test and evaluation. Problems arise because the number of test units is often understated. The assumption is made that a single unit can support several test and evaluation functions. Tests run longer than anticipated, they must be performed several times, and as a result, test units are not made available to begin the next set of tests. Schedules are then disrupted, and the money that was initially saved by providing fewer test units may be lost by falling behind schedule. Cost estimators must work in conjunction with engineering and test personnel to carefully determine the number of needed test units. If this situation cannot be reconciled, the risk analysis section of the cost estimate should reflect the potential impacts of time and quantity constraints on the achievement of the development schedule (Ref. 4:p. 4-26).

The cost estimator is also concerned with the schedule if there is an overlap between the development and production phases of a program. If production occurs while development testing is taking place, there is a likelihood that changes in configuration will result. Units that have been produced will be required to incorporate changes which evolved from the development testing process. This is accomplished through configuration modification which naturally increases the total program cost. This phenomenon was readily apparent in the Sea Nymph Program and is further discussed during the presentation of the case study.

When considering schedules, the cost estimator must, above all else, avoid over optimism. Failure to incorporate a judicious amount of pessimism into a program can lead

to schedule slips and cost growth. Unanticipated changes can render even the most exhaustive costing efforts useless.

10. Acquisition Strategy

Acquisition strategy is an integral component of a weapon system's cost. In the case of Government procurement, the Government attempts to structure contracts to reduce their risk and maximize the value of their dollar expenditures. The most widely publicized acquisition strategies are probably competition versus sole source procurements and multi-year procurements. The reason for introducing and using these and other strategies is a relatively simple concept: cost savings. The cost estimator must not only be technically competent with the various forms of acquisition strategy, but he must also be able to analyze them and recommend which strategy should be applied to a specific program.

> The key question that must be addressed is whether or not the initial investment required to establish and maintain competing contractors is less than the savings that result from negotiating cost in a competitive environment. (Ref. 4:p. 4-31)

In order to answer this question, the cost estimator must closely examine market conditions and availability of manufacturers, review applicable studies and models, and be intimately familiar with the program being estimated.

11. Ground Rules and Assumptions

The discussion now turns to the ground rules and assumptions which may influence the cost estimator's behavior and also influence cost. Very often, ground rules are imposed on the cost estimator, but when this is not the case, he must exercise judgement to establish assumptions so the estimating process can be completed. Top management should participate in the formulation of ground rules and assumptions because they could easily invalidate an estimate by changing a single assumption. The risk analysis portion of an estimate should incorporate allowances for the various assumptions and the estimator must ensure they are all accounted for. By accounting for variances from

assumptions, sensitivity analysis can be conducted by management to gain an in depth perspective of the program. Specific ground rules and assumptions are germane to every program. The following discussion includes the most general which are: production, schedule, cost limitations, time phasing, base year, inflation indices, participating agency support, Government versus contractor furnished equipment, and contractor relationships.

a. Production Schedule

The cost estimator prefers to perform a detailed schedule evaluation prior to commencing the estimating process. Now armed with an awareness of potential schedule problems such as over-optimism, the cost estimator can attempt to reduce risk or allow for it in the risk analysis section of the estimate. Without an assessment of the schedule, the estimate will only be as accurate as the accuracy of the schedule on which the estimate is predicated. The estimator must clearly identify the schedule ground rules and assumptions. Unanticipated schedule changes will have a profound impact on the cost of a program.

b. Cost Limitations

When a cost limitation for a program is established, various program options are weighed according to their cost. The cost estimator must document which program alternatives have been selected to ensure the validity of his estimate. Each option should be accompanied by a risk assessment which further defines the cost implications of each given option. Whenever a program scope or cost limitation is imposed, it must be documented as part of the estimate's overall ground rules and assumptions (Ref. 4:p. 4-40).

c. Time Phasing and Base Year.

Time phasing is the process of allocating costs to specific Government fiscal years. It can also be defined as spreading a program's cost estimate out over the

program schedule. How much cost is spread to a particular year is dependent upon the amount of activity scheduled for that year.

> Clues to schedule anomalies and risk become more evident when the estimate is time phased and unusual peaks and valleys appear or exceptionally high funding levels are required to carry out scheduled effort in a particular year. (Ref. 4:p. 4-41)

Once an estimate has been determined, it is usually expressed in constant dollars. From this point on, real program cost growth can be tracked and contrasted with program growth caused by inflation. Another purpose of time phasing is to convert constant dollars into projected year dollars so the estimate can be used in budget submissions. The cost estimator must identify the dollar years were used to develop the estimate and the base year.

d. *Inflation Indices*

Inflation indices disseminated by the Office of the Secretary of Defense (OSD) are widely used by the various services, but program peculiar indices are used occasionally. The cost estimator should identify as a ground rule the specific OSD index he is using because so many have been issued.

e. *Participating Agency Support*

Participating agencies can refer to other services or other Government agencies. Success of a program is often contingent on the performance of a participating agency. So too is the accuracy of an estimate dependent upon on a participating agency. The conditions of an agreement with a participating agency must be clearly understood by the cost estimator and management because of the potential impact on cost and schedule.

f. *Government Versus Contractor Furnished Equipment*

Contractual agreements between the Government and contractors for equipment support are similar to participating agency arrangements. Failure by either party to furnish equipment identified by contractual obligation, results in additional cost due to

schedule delay. The cost estimator cannot predict late deliveries, or a total failure to deliver anything, so he must state in his assumption that the estimate is based on the responsible parties providing the equipment that they are contractually liable for.

g. *Contractor Arrangements*

The type of contractual arrangement that the Government and contractor enter into must be defined in the ground rules and assumptions because of the cost implications. A cost estimator may initially present an estimate without regard for the type of contract. The result, referred to as a baseline estimate, would then be adjusted as appropriate for the acquisition strategy which is adopted. Contract types are both numerous and complex. The estimator must be familiar with them and incorporate them into his estimate when applicable. Appendix B provides a discussion of contract types.

At this point, the cost estimator has performed most of the background work necessary to develop an estimate. Completed tasks include: determining the use of the estimate, identifying the level of detail required in the estimate, establishing physical and performance characteristics, understanding the influences of technology, system configuration and the testing process, and establishing the ground rules and assumptions. The cost estimator must still complete several preliminary, yet extremely important tasks. An estimating methodology must be selected, but this step must be preceded by an identification of the cost elements.

Cost elements can be obtained from a program's Work Breakdown Structure (WBS). The WBS is a method of defining and diagramming the manner in which the work of a program is to be accomplished by separating the work content into individual elements. The cost estimator identifies the cost elements in the WBS which reflect the scope of the program. A cost estimating method is now selected for each cost

element. A brief discussion of commonly used cost estimating methods, which includes parametric, grass roots, analogy, and expert opinion, follows.

12. Cost Estimating Methodology

a. Parametric

The parametric method is used more often in the early stages of a program, which would include the concept exploration and demonstration and validation phases. This method is based on the existence of a relationship between a performance or physical characteristic and cost. The relationship between the characteristics or variables and cost are referred to as cost estimating relationships (CER). The CER is expressed in a mathematical equation with cost being the dependent variable and the characteristics being the independent variables. The parametric method permits cost to be projected even though the independent variable values differ from those that were originally used to develop the mathematical relationship. The ability of a CER to accurately project costs diminishes as the value of the variables moves away from the values that were used to formulate the CER. Learning curves are commonly used as a CERs where quantity is the independent variable and cost is the dependent variable.

Parametric estimating requires an extensive amount of data and the cost estimator must be able to recognize the variables which have a valid relationship with cost. After they have been developed, CERs must be updated and refined whenever new data are obtained. This new data adds to the data base and gives a more accurate reflection of the situation the cost estimator is trying to create. (Ref. 6:p. 15)

The major advantage of parametric cost estimating is that it permits the development of an estimate in a short period of time even though the program has not been clearly defining. Another advantage of parametrics is based on actual program cost history so they reflect the impacts of system growth, schedule changes, and engineering changes

(Ref. 4:p. 3-23). Limitations of parametric methodology include a heavy reliance on extensive data and the fact that costs are presented at a very high level which does not permit analysis of detailed areas or the breakdown of the estimate into individual cost categories. The use of factors and ration also falls into the realm of parametric estimating.

b. Analogy

The analogous cost estimating method, also referred to as the comparative method, is based on the assumption that no new program advances the SOA so drastically that it represents a totally new system. Comparisons are then made between the actual costs of an old system and a new system. This comparison and analysis is conducted at the component or parts level. Adjustments are made for complexity, technological change, and physical differences to develop an estimate for the new system. A thorough engineering analysis must be conducted to ensure the comparisons, and the cost estimate, are valid. When comparison and analysis can be achieved at a lower level, like the individual part level, the analogy will be much more thorough. This results in a more accurate cost estimate.

Analogy estimates are better suited to situations where technology is advancing quickly. In these situations, the parametric methodology may not be as accurate because the CERs are quickly invalidated. Supporters of analogy estimating contend that seldom, if ever, is anything so entirely new that analogy estimating methods cannot be used.

> Most new programs consist of modified or improved versions of existing components, combined in a new way to meet a new need. (Ref. 4:p. 9-6)

There are several somewhat negative aspects of the analogy method. Detailed cost data must exist for the system being used to compare with the new system. Without this data, the cost estimator cannot transition from an old system to a new. This method is dependent on engineering judgement. Without accurate support in this area,

estimates are invalid. Finally,analogous estimates use a simple historical data point as the basis for a cost estimate, or a portion of one. There is a risk in basing an estimate on such limited grounds. One definition of analogous cost estimating methods includes the phrase, "based on historical data too limited to allow statistical estimating" (Ref. 4:p. 9-50).

c. *Grass Roots*

This method is also referred to as the engineering approach or the detailed estimate. This method of estimating requires dividing the cost of a system into elements such as material, labor, indirect costs, overhead, and profit. These cost elements are then applied to the subtasks or functional level of a WBS. The prices of each subtask are summed to arrive at the total cost of a system. This method is based on the assumption that historical costs of a system can predict future costs of the same and other similar systems. The engineering approach is manhour intensive and requires actual, current data. Many defense contractors still employ this method as their primary means of estimating costs.

d. *Expert Opinion*

This method requires the personal knowledge of an individual who is an expert in the area to be estimated.

> In its simplest form, this approach to estimating consists of an individual providing a probable cost based on personal knowledge of similar items or the amount of work needed to perform a task. (Ref. 6:p. 14)

Expert opinion often embodies group or consensus opinion through formal approaches such as the Delphi Technique.

Problems arise with this method when a true expert cannot be found or the expert cannot support the results with guantitative analysis or data. This method is most useful in the early stages of a system acquisition when there is little data to rely on. It is also useful as a cross check for an existing estimate or in combination with other methodologies.

e. *Other Methods*

Several other methods are used to a lesser extent and for specific uses. The following is a list and brief description of these methods:

- Catalog or Handbook Estimating. Costs off-the-shelf components within a larger system by using reference books
- Manloading Method. An experienced estimator projects the number of individuals, and their skill levels, needed to complete a specific work effort.
- Individual Engineering Standards. Standard hours are used, normally in a manufacturing environment, to estimate the time to complete an operation.
- Estimates-at-Completion. This estimate is obtained from performance measurement data submitted by the contractor. Trends and variances are used to predict future costs.

There are numerous estimating methods. Some are better suited for specific tasks, while others can be widely used for a broad spectrum of estimating requirements. Some methods are more applicable to the individual phases of the acquisition process. A cost estimator will usually use several methods when estimating an entire system and conduct a cross check with a different method whenever possible. The choice of methodologies should be made only after careful consideration of factors such as: adequacy of program definition, level of detail required, availability of data, and time constraints (Ref. 4:p. 3-28).

13. Other Factors

This final portion of the cost estimating discussion presents several aspects of the estimating process in more detail. These topics include the development of CERs, normalization, data sources, learning curve, and cost models. All are basic, yet important concepts which must be understood in order to develop an accurate cost estimate. While this compilation of relevant topics is by no means inclusive of all the cost estimator's concerns, it does provide some rudimentary insight into the task of developing an estimate.

a. *Learning Curve*

Learning curves are referred to by a variety of names which include: cost improvement curves, progress curves, cost/quantity curves, and experience curves. All cost improvement or learning curves generally fall into two categories of mathematical models. These models are called the unit curve and the cumulative average curve. The equations for each are similar, but differ in defining the cost or hour term, and as a result, different total cost or hour values are computed for the identical first unit of production (T_1) and slope values.

Learning curve theory is based on the assumption that as the quantity of items produced increases, cost decreases at a rate which is predicable. This rate is described by the unit curve model and the cumulative average curve model. The equation for unit curve is:

$$Y_x = T_1 \; X^b$$

Where:

Y_x	=	The cost required to produce the xth unit
T_1	=	The theoretical cost of the first production unit
X	=	The sequential number of the unit for which the cost is to be computed
b	=	A constant reflecting the rate costs decrease from unit to unit

The equations for the cumulative average curve is:

$$\bar{Y}_x = T_1 \, X^b$$

Where:

$\bar{Y}_x$	=	The average cost of the first X units
T_1	=	The theatrical cost of the first production unit
X	=	The sequential number of the last unit in the quantity for which the average cost is to be computed
b	=	A contrast reflecting the rate costs decrease from unit to unit (Ref. 4:p. 7-9).

The only difference between the two equations is in the definition of the Y term, otherwise they are the same. The unit curve describes the relationship between cost and individual units, while the cumulative average curve describes the relationship between average cost and differing quantities of produced units. Both curves substantiate that a decrease in cost is experienced at a constant percent each time the quantity doubles. This is reflected in both curves through the value of b, a constant which reflects an amount of decrease for every doubling of quantity. The b value for both the curves is computed as follows:

$$b = \frac{\log S}{\log 2}$$

Where:

S = The cost/quantity slope expressed as a decimal value. (Ref. 4:p. 7-10)

As an example using the unit curve, if the first unit cost 100 and the second unit cost 90, or 90% of unit 1, the unit curve would have a 90% slope and the s value would be 0.9. The resulting b value would be the log 0.9/log 2 or -0.045758/0.30103 or 0.15200. The b value is determined in the same way for the cum average curve. However, using the same first unit T_1 value and slope, one will always get lower cum total costs using the cum average curve because of the difference in how Y_x and $\overline{Y}_x$ are defined. In the example above where the first unit cost 100 and the second 90, the total cost for the two is 190, based on use of the unit curve. Using the cum average curve the Y_x for the same T_1 value (100), slope value of .9 and x value of 2, would yield a total cost of 2 times 90 or 180. (Ref. 4:p. 7-10)

A cost estimator must know which of the two curves he is working with since they yield different results. This includes knowing which model to apply for a given situation, and knowing which curve was used to obtain slope values when the only available information is the historical slope data.

Cost improvement curves are both widely used and understood throughout the Government and private industry. They are a common tool of the cost estimator and must be thoroughly justified because most managers have some level of working knowledge and constantly challenge the estimated costs. This occurs because for large

quantities of produced units, 100 for example, a small change in slope can result in a large change in the total cost.

b. Cost Estimating Relationship (CER)

CERs can be based on reasoning or historical data, but it is preferred that they relate cost to design or performance parametrics. CERs can be divided into groups which correspond to the acquisition cycle and include: R and D, production, and operating and support. This differentiation is important because the groupings serve as guides to the cost estimators in searching out cost drivers which can be used in developing the estimating relationship (Ref. 4:p. 6-25). CERs can also be classified according to the level of detail they estimate. Relationships can be developed which estimate at the system, subsystem, and component levels. A third way of classifying CERs is predicated on the type of cost drivers which are utilized to predict costs. Weight is probably the most common cost driver. Physical, technical, and performance characteristics and parameters are categories which cost drivers are divided into. Table 2 is an example of possible airframe cost drivers that a cost estimator would consider when developing CERs for a particular airframe (Ref. 4:p. 6-29).

Other more sophisticated variables are used to develop CERs, an example of which is the technological level of the system in relation to the current SOA. Technology has long been recognized as having a significant affect on the cost of a system. The problem arises in attempting to quantify by how a system has or will advance beyond the SOA.

Cost estimators have used several methods to deal with this problem. One method uses the year of development as a substitute for technological advance in developing the CER. A second method counts the number of advances or new designs

TABLE 2

AIRFRAME COST DRIVERS

Physical

- Airframe Weight
- Empty Weight
- Wing Span
- Thrust
- Avionics Weight
- Performance
- Range
- Speed
- Payload

Environment

- Maintenance Levels
- Support Concept

Mission/Function

- Close Air Support
- Interceptor
- Bomber
- Multi-Mission

Time

- Date of First Flight

Technological Advance

- Level of Technical Advance Required

which have been implemented since the first system was placed in operational use. A third method requires the cost estimator and systems engineers to subjectively select a value for technical advance or system complexity.

> This sometimes is represented by a continuous variable running from O (off-the-shelf, no new technology) to some number N (brand new technology, major advance in SOA demanded), or sometimes is represented by a simple O-1 variable, where 1 indicates a major technical advance is required, and O indicates no technical advance is required. (Ref. 4:p. 6-28)

CERs are most valuable in the early phases of the system acquisition process. More detailed estimating methods can be applied later in the process when more is known about the elements of cost. CERs are used by many defense contractors in developing bids, or as a cross check when other estimating methods are employed.

In conclusion, the primary objective of CERs is to express the relationship between cost and some characteristic or parameter. Very often, several CERs are used to develop as estimate. This is how cost estimating models are usually developed. Regression analysis is one of the more common ways to construct functional relationships between cost and system characteristics.

c. *Data Sources*

Most sound cost estimates have been logically extrapolated from historical cost data (Ref. 4:p. 5-2). Naturally, the collection and analysis of this historical data is of paramount importance to the cost estimator. An initial consideration of data collection deals with the source, specifically, whether it is primary or secondary. Even though there are exceptions, primary data are usually preferred over secondary data. Exceptions to this rule include accessibility of primary data, time constraints, and cost of collection.

Historical data are valuable because the cost estimator is provided with trends for specific costs associated with an individual contractor. The data also permits the estimator to make assumptions regarding general cost trends for systems within a given

family. Armed with this information, the estimator is able to construct CERs and cost models for individual contractors or specific systems. Cost data is the building block of the cost estimating process (Ref. 4:p. 5-5).

Historical data does have several inherent limitations which the cost estimator must be aware of in order to develop a reliable estimate. Adjustments must be made to historical costs when they are used to estimate a new system. This occurs when an analogous method is used and new system modifications have occurred with regard to performance characteristics, manufacturing methods or raw materials. Historical costs will not account for these changes in a new system and must be calibrated to effect a valid estimate.

It is important to determine the appropriateness of historical data in order to develop a specific cost estimate. The following questions can help the cost estimator determine the applicability of data. These questions focus on particular issues which are relevant to deciding the value of specific historical cost data to a cost estimating task. The questions are:

- Does the data require normalization to account for differences in base years, in inflation rates, and in differences arising from a calender year versus fiscal year accounting system?
- Is the work content of the current cost element consistent with historical cost element?
- Does the data reflect actual costs, proposal values, or negotiated prices and has the type of contract been considered?
- Is there sufficient cost data available at the appropriate level of detail for utilization in statistical measurement?
- Are cost segregations clear so that recurring is separable from non-recurring and are functional elements?

Historical cost data are available through numerous sources. The cost estimator must decide the appropriateness of data to the task confronting him and document his assumptions in the application of this data.

d. Normalization

Normalization is defined in the 1982 version of the Air Force Space Division Unmanned Spacecraft Model as an attempt to refine (i.e., to render constant) cost data through the measurement and subsequent neutralization of the impacts of certain external influences. These external influences must be quantified even if the measurement is subjective in nature. The adjustment of actual cost data to a uniform basis has two definite objectives: to improve data consistency so that any comparison/projection is more valid and to allow the use of all credible data points without regard to homogeneity (i.e., to expand the number of comparable data points). (Ref. 7)

The normalization of data falls into two categories: normalization for economic changes and normalization for other than economic changes. Normalization for economic changes is necessary, for example, because the price of goods and services changes over time. Indexing is the statistical mechanism which measures the effect of the changing value of the dollar over time (Ref. 4:p. 5-38). With regard to cost estimating, index numbers are used to inflate or deflate costs so consistent comparison can be made. By eliminating the effect of inflation, estimators and analysts are able to compare various costs on a constant year dollar basis. When a similar system has been purchased in the past, learning or cost improvement curve analysis methodology can be applied to historical cost data expressed in current dollars to estimate future procurement costs. The use of cost improvement curves is an example of regression analysis (Ref. 4:p. 5-40).

There are three general types of indices: quantity, value, and price. Price indices are primarily used by cost estimators because they are interested in cost data, rather than quantity or value data. The three general types of indices branch off into numerous index numbers which are designed for specific purposes and classified according to construction method. Cost estimators frequently use inflation indices published by the

Office of the Secretary of Defense (OSD). Use of these indices is mandatory in the preparation of all military program office financial reporting (Ref. 4:p. 5-56).

The cost estimator must be familiar with the use of index numbers in many different forms because they are so frequently used. Cost estimators associated with any type of defense procurement will encounter indices published by OSD and must be able to apply them correctly. Correct application requires a thorough knowledge of the fundamentals and of the manner in which they were derived.

Normalization for other than economic changes encompasses several areas, which include: technological change, complexity, work content differences, and cost accounting structure differences. Technology normalization is designed to account for the advance of technology over time. Since technology becomes more current, historical cost data must be updated if it is to be used to project cost estimates.

> For example, an item built in the early 1960s, which extensively employed solid state/integrated circuitry technology, may have been, at that time, an SOA activity and would have correspondingly high high costs associated with it. The same activity could be accomplished in the 1980s with an off-the-shelf piece of equipment and the costs would be minimal. (Ref. 4:p. 5-78)

Closely related to technology normalization is technology forecasting. Technology forecasting has been defined as:

> A quantified prediction of the timing and character of degree of change of technical parameters and attributes associated with the design, production, and use of devices, materials, and processes, according to a specified system of reasoning. (Ref. 8)

This quantified prediction is an extremely subjective matter because relative states of technology must be identified and documented at various points in time. The cost estimator is attempting to recreate the engineering learning process that occurs with the passage of time. The study of technology advance is regularly addressed in Technological Forecasting and Social Change.

Various methods of measuring technology advance have been proposed for specific families of systems (i.e., spacecraft) (Ref. 9). Unfortunately, there seems to be a lack of communication between the technological forecasting and cost estimating communities. Ideally, knowledge that can be from these two communities can be combined to produce technology factors that be used to develop more sophisticated and predictive CERs.

Design complexity normalization is also very subjective because there is no definite and concrete method of measuring a system's complexity of design. The objective is to quantify complexity by identifying significant operational criteria which can relate a degree of complexity to cost. After this is achieved, the operational criteria must be described to permit a viable assessment.

Work content normalization ensures that cost elements included in a system's historical cost data are the same elements that are used to estimate a similar system's cost. The cost estimator must be aware of the types of costs that are included in historical cost data so that appropriate additions or deletions can be made to ensure the correct cost elements are reflected in the cost estimate.

Normalization for cost accounting structure is designed to adjust for differences such as direct versus indirect charging and the calculation and application of overhead. For example, normalizing historical cost data may require the deletion of specific direct charges so that the data is compatible with an accounting structure that charges these types of cost as indirect within various overhead pools (Ref. 4:p. 5-82).

Normalization requires the recognition of incompatibility between historical cost data and its functional use as a valid aid to cost estimation. Even if complete adjustment through normalization is not possible, the cost estimator must at least be aware of these incongruities so he can compensate for them in developing a cost estimate.

e. Cost Models

This discussion is limited to a general description of cost estimating models and the presentation of the Unmanned Spacecraft Model developed by the Air Force Space Division and the RCA-PRICE-Hardware model. These two models are discussed because of their focus on technological advance factors.

(1) **General.** Cost models, generally based on CERs, were primarily developed to project cost estimates when relatively little information about the system being estimated is available. A cost model has been defined as an estimating tool consisting of one or more CERs, estimating methodologies, or estimating techniques used to predict the cost of a system or one of its lower level components (Ref. 4:p. 8-2). This ability to predict costs has never been more important. Accurate predictions early in a system's life are critical to budgeting efforts. Many examples have been documented in DOD weapon system acquisition that attribute cost overruns to inaccurate cost estimates early in the program's history. Effective use of parametric cost models can improve this situation because of their suitability for estimating the early phases of a system's life.

> Both the General Accounting Office (GAO) and DOD have indicated that by the time a system completes the Concept Formulation stage, 70% of the life cycle cost has been determined, i.e., has been fixed by the choices made to that point in the life cycle. By completion of the System Definition stage, 85% of the cost is determined. (Ref. 10:p. 1)

Even though parametric cost models are especially useful for early estimates, they can be equally effective for just about all phases of a program's life. The following quote, taken from a DOD study conducted over a decade ago, elaborates on the merits of the parametric cost approach. Mention should be made that cost models have been developed since this study which perform effective cost estimating for phases other than early concept exploration and initial development.

> ...estimates for new weapon systems acquisition costs are either derived from detailed, grass root calculations (the industrial engineering approach) or based on relationships between more aggregated components or system cost and the physical and/or performance characteristics of the system. These relationships should be derived from cost histories on prior programs. The latter method is often called the parametric approach. It is clear that, during the early phases of the acquisition process, only limited design information is available and considerable uncertainty surrounds both this information an whatever planning data is available on how the new system will be developed and produced. Nonetheless, cost estimates must be made. Both the fact of limited and uncertain information on which to base estimates, and the use to be made of these cost estimates, strongly suggest the employment of parametric estimating procedures. The parametric approach is particularly suited to making estimates based on limited physical and performance information.
>
> For most new systems, the parametric approach is the only method that can be used to make an estimate from the limited information available during concept formulation, i.e., when only mission and performance envelopes are defined. Only subsequently when detailed contractor proposals are being prepared can the industrial engineering procedures be applied. Furthermore, parametric methods provide the analyst with an inexpensive means of examining the impact on cost of a variety of changes in system performance requirements--information of particular importance during the early phases of the development and planning processes. (Ref. 10:p. 2)

The actual estimating that occurs through the application of a cost model occurs by using either CERs based on performance and physical characteristics, and operational parameters, or matrix or table values which yield a cost estimate that, again, is based on characteristics and parameters. Regardless of the methodology or the model, the cost estimator must know how to use models in tandem when necessary, and even more importantly, when and how to apply the appropriate cost models.

The following set of questions must be fully understood before a cost estimator can use a model to develop an estimate. By resolving these questions, the estimator can establish a level of confidence in his estimate and realize what, if any, action must be taken to transform the model's output into an estimate which meets the preliminary objectives of the final user. The questions are:

- What phases are included in the model estimate?
- Is the data required to use the model available?
- In what units of measure is the output of the model stated?

- Does the model include overhead, general and administrative expenses, profit, or any other loadings?
- Does the model include non-recurring and/or recurring costs?
- Does the model include support costs such as systems engineering/project management, data, training, etc.?
- What is the confidence level of the cost estimate which is generated?
- What ate the statistical measures of validity for the regression equation?
- What is the source and content of the data base from which the model was developed?
- What is the technological age of the data base?
- What is the range of input values for which the model is valid?
- Is the data base from which the model is developed similar to the requirements and acquisition approach which will be used for the item being estimated?
- Are cost improvement or learning curve algorithms used and what assumptions are they based on?
- Does the model include inflation and what indices are used?
- What types of systems has the model been validated for?
- Does the model require calibration? (Ref. 4:p. 8-6)

The use of cost models has increased consistently since their initial development. The need for quick accurate budgeting figures early in a program's life, coupled with increasingly complex weapon systems, has elevated parametric cost models to a new level of importance in the cost estimating environment.

(2) RCA Hardware Cost Estimating Model (PRICE H). The RCA PRICE family of parametric cost estimating models now consists of five specifically tailored models. The five models are:

- PRICE H - used to estimate development and production costs of hardware products and systems.
- PRICE HL - used to estimate maintenance and support costs of hardware products and systems.
- PRICE S - used to estimate design, test, implementation and integration costs for computer software.
- PRICE SL - used to estimate software maintenance, improvement, and growth costs during operation.

- PRICE M - used to estimate development and production costs of microcircuit components.

The PRICE H model is included in this discussion because it is used primarily for estimating development and production costs. This appears relevant to any effort which would attempt to estimate the costs associated with an SOA extension. The model also places emphasis on complexity, a factor which may have an affect on the cost of advancing the SOA.

This acquisition cost estimating model is a computerized means of developing cost estimates for electro-mechanical hardware systems and components (Ref. 11:p. 6). PRICE H contains thousands of proprietary mathematical equations which express a relationship between the numerous input variables and cost. Each individual set of input variables uniquely defines the hardware which is being estimated through physical and performance characteristics such as weight, volume, electronic density, and environmental specification level. The cost estimate is determined from the CERs or mathematical equations which are developed from parameters and characteristics of the weapon system which are mentioned above. The PRICE H model yields estimates for the development, production, modification, integration, and assembly of hardware systems, demonstrating its versatility.

The primary cost drivers in the PRICE H model are electronic weight, electronic manufacturing complexity, structural weight, and structural complexity. As a system becomes more complex to produce, the cost of producing the system increases at an increasing rate. Electronic manufacturing complexity represents a system's components, packaging density, and manufacturability. Structural complexity portrays the system's mechanical/structural material type, finished density, and fabrication methods. Selecting the correct complexity factors is one of the key activities in executing the PRICE H model. (Ref. 4:p. 8-15)

Price H was designed to estimate costs even though a minimal amount of hardware information is available. This makes it especially conducive for estimating of programs in the conceptual stage of development, since the model uses internally generated values for any missing input variables (Ref. 11:p. 7). Obviously, with more input variables available, a higher level confidence can be attached to the estimate.

Since PRICE H is a parametric model, parameters are used to calculate costs. The fundamental parameters used in the PRICE model are listed below:

- Quantities of equipment to be developed, produced, modified, purchased, furnished and/or integrated and tested.
- Schedules for development, production, procurement, modification, integration and testing, including lead time for set-up, parts procurement, and redesign.
- Hardware geometry consisting of size, weight of electronic and structural elements, and electronic packaging density.
- Amount of new design required and complexity of the development engineering task.
- Hardware structural and electronic design repeat.
- Operational environment and specification requirements of the hardware.
- Type and manufacturing complexity of the structural/mechanical and electronics portions of the hardware.
- Fabrication process to be used for production.
- Pertinent escalation rates and mark-ups for General and Administrative charges, profit, IR &D, cost of money, and purchased item handling.
- Technological improvement.
- Yield considerations for hardware development. (Ref. 11:p. 6)

Understanding that interrelationships exist between the parametric inputs is critical to understanding how the model works. If one parameter is changed, this change is not localized to only one cost element, but it will most likely have a direct effect on a few cost elements and an indirect effect on many others. This dynamic effect is characteristic of most of the input variables (Ref. 11:p. 7).

Adapting the PRICE H model to estimate a variety of systems is accomplished through calibration, a function which is dependent on the availability and validity of data. If this condition can be met, adaptability is one of the model's greatest assets.

(3) **Unmanned Spacecraft Cost Model (USCM).** The USCM is based on actual cost data from military and commercial satellite systems and is based on close to twenty years of experience. This particular model is discussed because it introduces complexities which many parametric models do not deal with (Ref. 7:p. iii). These complexities exist because of the sophisticated nature of spacecraft design and production, and their common use of SOA technology. Dealing with complexities of this nature may contribute to a better understanding of SOA advance in general.

The USCM was first published in 1969 and is currently undergoing its sixth update. As a part of each update, additional data was collected to revise CERs, apply normalization techniques, and incorporate sensitivity analysis capabilities. The controlling officer for the USCM, Air Force Space Division, believes the validity and the accuracy of the model increase with each update and addition to the data base.

The data used to develop the model's CERs represent many different levels of technology and complexity. Since so many levels of data are employed by the model, adjustment is referred to as normalization. The normalization process refines the basic cost data in an attempt to account for influences of alternate designs, varying levels of complexity, different technologies, and inflation (Ref. 7:p. V-1).

The normalization technique attempts to adjust the actual cost data with respect to several quantifiable subjective parameters. The parameters which were selected are technology carryover and complexity of design. By neutralizing the influences

of these two parameters, more data could be used and more comparison studies between various systems could be conducted.

The spacecraft programs which comprise the USCM data base were easily distinguished by the period in which they were developed and produced. Each program experienced benefit from its predecessor in the form of technical knowledge. Technology carryover attempts to account for the cost impact of this technology advance. In order to accomplish this, the state of technology had to somehow be measured.

> For example, a program that commenced in 1963 would be evaluated in terms of the limited state of technology at that time, and a 1970 program would be evaluated in terms of the state of technology in 1970. (Ref. 7:p. V-2)

The objective of technology carryover is to capture the learning process. Changing SOA levels must be measured over time and incorporated into the cost estimate. Table 3 defines the technology carryover measurement scale (Ref. 7:p. V-4).

Systems must also be evaluated in terms of the relative complexity of their subsystems. In order to measure complexity of design, certain operational criteria had to identified which could be related to cost. Then each operational criterion had to be described to permit a valid assessment which could be measured. The USCM evaluates operational criteria on a base value of 1.00, which is associated with the idea of baseline relative complexity. This evaluation is also based on the relative importance of the subsystem to the overall cost of the system. Matrices have been developed for each type of subsystem to assist with measurement of design complexity, and determining its cost impact. (Ref. 7:p. V-6)

A RAND Corporation study evaluated the USCM with other spacecraft cost models and concluded that it appeared to be the most reliable for the user who lacks detailed knowledge of a program and is interested in obtaining an estimate based on basic spacecraft characteristics. The lack of detailed knowledge and the affects of

TABLE 3

MEASURE OF GENERAL ENGINEERING KNOW-HOW

Engineering Know-how Level	State-of-the-Art	Production Experience	Specification Status	Operating Program Characteristics (OPC)
1.00	The item is substantially Beyond the current state-of-the-art. Major development work is requrired.	No production of any kind has been started.	No work on specification has started.	None of the OPC for using the items have been formulated.
0.75	The item is slightly beyond the current state-of-the-art. Some developmet work is required.	Experimental laboratory fabrication of a similar item is in process.	Work on a specification is in an early stage and only general requirements are identified.	The general outline of OPC under which the item will be used has only been tentatively defined and many specific details are lacking.
0.50	The item is within the state-of-the-art but no commercial counterpart exists.	A prototype of the item has been produced.	A specification for the item has not been completed but a specification on a similar item is applicable.	The general outline of OPC has been formulated but many specific details are lacking.
0.25	The item will involve a minor modification of commercial or standard issue items.	The item has been produced in limited quantity.	A specification for the item has been prepared but it is under review or revision.	The OPC have been substantially defined but are under review or revision.
0.10	The item will require no modification.	The item has been produced in production quantites.	The specification is for the item as produced.	The OPC have been defined and are met by the item.

technology advance and design complexity may have direct relevance to the measurement of SOA advance and the cost of this advance.

This concludes the discussion of cost estimating, a discipline which is really at the heart of SOA measurement and SOA advance cost estimating. The following section presents several ideas specifically on SOA measurement and the cost impact of SOA advance.

C. SOA MEASUREMENT

1. Introduction

A primary objective or natural fallout of R and D is the advancement of technology. Measuring SOA advance and providing cost estimates for SOA advance is a complex task. Many postulations and hypotheses have been offered, but very little practical application exists in the real world cost estimating process. Various cost estimating models attempt to compensate for the impact of technology advance on cost estimates through the application of complexity and technology factors to CERs. While these efforts represent significant progress, the impact of SOA advancement on cost estimates continues to be an area of uncertainty to the cost estimator. If the cost associated with SOA advance is to be estimated with any degree of accuracy, it must be reflected in parametric cost analyses (Ref. 10:p. 63). The following discussion on methodologies which account for technological advance is based primarily on the work of Dr. Edward N. Dodson, Director Economic Resources and Planning Group of General Resource Corporation, Santa Barbara, California.

2. SOA Surfaces

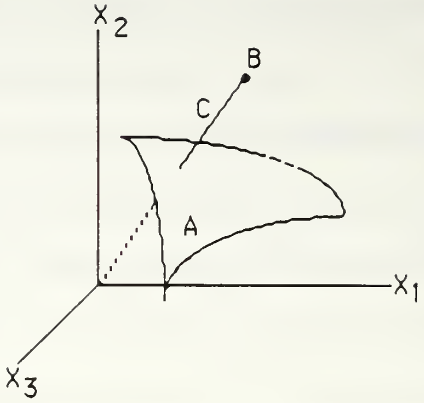
The objective of this effort to quantify SOA advance was to identify surfaces which represented the SOA at specific points in time. This was accomplished by

identifying performance and physical characteristics which were used to bound the SOA at that time. A period of time was chosen so all the systems looked at are equal in terms of the characteristics being used to define the SOA surface. The SOA surface is obtained by filtering several systems' actual data to a space which is described by the characteristics or technology parameters (Ref. 10:p. 42). The resultant space or surface is a representation of the SOA at that time as depicted by the actual characteristics of several similar systems. Similar systems built subsequently are then measured against the SOA surface to obtain a quantified measurement of the degree to which technology was advanced. Figure 2 is a generic graphical representation of this methodology to measure SOA advance (Ref 10:p. 43).

This approach is based on the following assumptions:

- SOA changes over time as new accomplishments are implemented as part of an industry's general technical capabilities.
- SOA for a particular system at a specific point in time is a function of numerous parameters.
- Systems with greater capabilities advance the SOA. Advance is measurable in terms of the SOA prevailing at the time of the new system was designed. (Ref. 10:p. 41)

The SOA surface approach does have two limitations. First, a large amount of data is necessary in order to fit SOA surfaces for successive periods of time. This does not present a problem when looking at systems which experience many development programs, such as computers, where plenty of data, in consecutive time frames, are available. Problems occur in systems where new development programs are spaced over varying and lengthy time periods. Secondly, the time period selected to hold system characteristics constant is selected arbitrarily. In short, two analysts working independently may not reach the same conclusion (Ref. 10:p. 44).



- Each axis (X_1, X_2, X_3) depicts a parameter
- Surface A represents the SOA at a particular point in time
- Point B represents a new system which depicts an SOA advance
- Line C measures the degree to which SOA was advanced

Figure 2. SOA Surface Approach to Measure SOA Advance

3. Time Regression Approach

Variations of the SOA surface approach have been developed which attempt to avoid the pitfalls of arbitrarily selected time periods. The variations from the SOA approach are, in their simplest terms, achieved by expressing the system's parameters as a function of time rather than fitting a specific surface to data for each individual period of time. A. Alexander and J. Nelson of RAND Corporation developed such an approach in their work, Measuring Technological Change: Aircraft Turbine Engines, The RAND Corporation, May 1972. This approach was implemented by Dr. Dodson as follows:

- A number of technical characteristics which encompass the technology of a particular class of systems, are set forth as independent variables in a multiple regression equation.

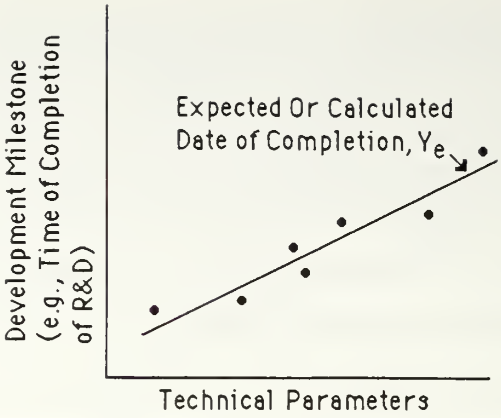
- The result of a multiple regression exercise is a function which can be interpreted as an expected date, Ye, for achievement of a given set of technical characteristics. These characteristics have been specified as independent variables previously.
- The residuals, Y_e-Y_{actual}, can be used as indicators of the extent to which each system was "before its time", or may have lagged behind the average. This is the measure of relative technological advance. (Ref. 10:p. 45)

Figure 3 is a graphical representation of this methodology (Ref. 10:p. 46).

Dr. Dodson states that extra development effort is required for a system to be ahead of its time, and that being "behind the times" should be correlated with a reduced effort. It is hypothesized that the residual, or SOA advance, in positively correlated with development cost.

Both the SOA surface and time regression approaches are predicated on the assumption that levels of technology can be expressed in terms of physical or performance variables which can be quantified. A limitation surfaces at this point because this is not the case for all systems, such as signal processing units where physical and performance characteristics are difficult to quantify. There are also trade offs among the two approaches with respect to the amount of detail which is used and the need to economize in the amount of data used in calibrating and verifying the estimating relationship. The time regression approach inherently permits the use of the entire data sample, but does not describe how performance variables change over time. In this approach, it is assumed the relationships between the various technology variables remain consistent. (Ref. 10:p. 53)

It is not possible, in some technical areas, to describe levels or states of technology with a reduced set of measurable parameters. In developing improvements in these areas, the emphasis is being placed on improved signal processing capabilities. Characteristics relating to signal processing are difficult to describe as scalar parameters. This reduces the ability to account for technology advance. (Ref. 10:p. 56)



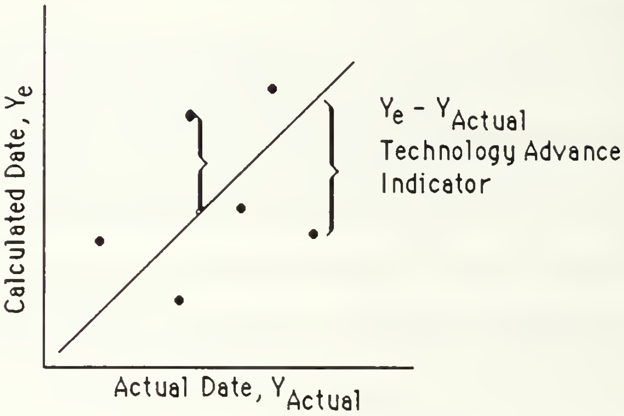


Figure 3. Time Regression Approach to Measure SOA Advance

D. BUDGETING

This discussion addresses some of the basic points of the budgeting process. It is included in this study because of its relevance to program planning and cost control. This brief synopsis of budgeting will provide the reader with some insight into cost control efforts employed by GTE Government System Corporation during the Sea Nymph Program. Also, information generated through the budgeting process is extremely useful for cost estimating purposes. The general budgeting process will be presented first,

followed by an introduction of The Cost/Schedule Control System Criteria (C/SCSC) which validated the management information and management control systems that were applied during the Sea Nymph Program. This section then concludes with a brief description of variance analysis.

1. General

The budget is more than just a forecast or prediction. A forecast makes no implications that management will take action so that the forecast actually occurs. A budget is a plan designed by management with the underlying assumption that they will take appropriate action to make actual events correspond to the plan (Ref. 12:p. 443). The budget process possesses the following characteristics:

- It is stated in financial terms, although these amounts may be supported by non-financial documentation.
- A budget usually covers a period of a year, but the Sea Nymph Program budgets covered the length of each individual contract.
- It contains an element of management commitment with managers agreeing to accept the responsibility to attain budgeted objectives.
- The budget is reviewed by several layers of management and approved by top management.
- Actual financial performance is compared to the budget and variances are analyzed and explained through management audit of the budget (Ref. 12:p. 444).

Where a forecast is generally perceived as a planning aid, a budget is viewed as both a planning tool and an element of control. Budgeting control systems utilize forecasting as one means of achieving control and coordination.

Budgets are divided into two categories: engineered expense budgets and discretionary expense budgets. The production controls presented in this study are engineered expense budgets because they are designed to measure efficiency, and operating managers have the responsibility for meeting budgeting goals. Discretionary expense

budgets are not designed to measure efficiency, and the budgeteer is responsible for only ensuring the budgeted amount is properly expensed.

Since GTE Government Systems Corporation is a defense contractor and primarily produces military weapon systems, their budgeting and control procedures are influenced by C/SCSC. For this reason, the budgeting and control function differs somewhat from traditional systems employed by organizations with no DOD affiliation. Basic concepts and theory from the management control system discipline are relevant, but traditional budgeting and control functions are introduced making minor modifications through C/SCSC.

2. Cost/Schedule Control Systems Criteria

C/SCSC are a series of rigorous test statements which are test points to assist in the evaluation of a defense contractor's management information system. It is not a system, it is not a report, and it is does not call for data. The requirements for report generation are governed by the type of contract under review and the dollar amount of the contract.

The criteria are designed to ensure the contractor's management control and management information systems include policies, procedures, and methods to comply with the requirements specified in DOD instruction 7000.2. Appendix B is a detailed listing of these requirements.

The cost performance Report (CPR) is the primary data source for this study. It is also the primary cost and schedule progress report for contracts which comply with C/SCSC requirements. The main thrust of this report is to display the time phased budget, the actual costs, and earned value which is the actual work completed for the money and time spent (Ref. 4:p. 5-26). The CPR is a monthly report which includes comparisons of planned work versus actual work performed and actual work performed versus actual costs

expended. An explanation of problems and the plan to correct these problems is also presented in this report.

CPR data are presented in five formats. The following is a brief description of each:

- The Work Breakdown Structure Report (Format 1) details costs usually down to WBS level three. Variances exceeding established thresholds are explained in Format 5.
- The Functional Categories Report (Format 2) reflects cost by the contractor's normal organizational departments or functional categories. This is normally the contractor's natural method of tracking costs.
- The Baseline Report (Format 3) traces all changes made to the original target cost. All changes to the Performance Measurement Baseline (PMB) are reported.
- The Manpower Loading Report (Format 4) uses the functional categories of Format 2, but tracts contract status in terms of man months.
- The Problem Analysis or Variance Analysis Report (Format 5) explains each of the variances presented in the previous formats and specifies corrective actions.

In order to effectively analyze CPRs and use them for cost estimating purposes, several concepts must be understood. The next and final section of this chapter discusses variance analysis and presents these concepts.

3. Variance Analysis

A variance is defined as the difference between actual and standard cost (Ref. 13:p. 22). A standard is also defined as a benchmark or norm for measuring performance and relates to the cost or quantity of inputs used to manufacture or produce a good or service. Quantity standards specify how much of a cost element, such as labor time or materials, should be used in producing a single unit of a good or service. Cost standards specify what the cost of this amount of time or these materials should be. Actual costs and actual quantities of inputs are measured against standard costs and standard quantities to determine if operations are occurring within the limits that management has established. (Ref. 14:p. 353)

As long as costs remain within the established standards, then no action is required by management. When costs fall outside these prescribed limitations, an exception or variance exists. Variance analysis requires the subdivision of the total variance so that management can assign responsibility for performance that is not within standards. Variances can be general or they can be very detailed and complex. The degree of simplicity or complexity is up to management's discretion, but variances should be broken down only to the point where they provide useful information to management for decision making purposes.

As a prerequisite to analyzing variances presented in CPRs, several concepts and definitions particular to the defense contractor environment will be briefly discussed. The discussion includes Budgeted Cost of Work Scheduled (BCWS), Budgeted Cost of Work Performed (BCWP), Actual Cost of Work Performed (ACWP), Schedule Variance, Cost Variance, Budget at Completion (BAC), Estimate at Completion (EAC), and Management Reserve (MR).

- BCWS refers to the amount of money set aside to perform a specific job. The job has been planned and scheduled, and the work scope is usually small so the BCWS estimate is usually accurate. When the work cannot be planned or scheduled because it will be accomplished in too distant time periods, the work is placed in Undistributed Budgets until definition and scheduling is possible.
- BCWP is also referred to as earned value and is a strong indication of a program's well being. It represents what was planned to be spent for what was actually accomplished. In other words, it represents the portion of work that was completed with the money identified in BCWS.
- ACWP is the amount of money that has been expended on a piece of work at a specific point in time. It is an accrued or accumulated amount which builds as the job progresses. Like BCWS and BCWP, it is expressed in dollars.
- Schedule Variance is the difference between BCWS and BCWP. It is expressed in dollars, a situation which often causes initial confusion until it is considered that work not only takes time, but costs money also. For example, a behind schedule position (BCWP<BCWS) requires at least the variance amount to get back on schedule. Schedule variance does not show the overtime, premium time, and impact on other schedules associated with a behind schedule situation. A positive schedule variance (BCWP>BCWS) is not necessarily an underrun or positive position. It

indicates a schedule position and represents the work that must be completed in order to return to schedule.

- Cost Variance is the difference between BCWP and ACWP. A negative cost variance (ACWP>BCWP) represents money spent, work not accomplished. A positive cost variance (ACWP<BCWP) is the preferred position and can result in an underrun. This variance can occur if excess budget has been allocated to the early stages of a contract. Front loading must be carefully controlled and analyzed.
- BAC is the accumulated total of BCWS projected to the end of the program. It represents the spending plan. When cost variances are low, BAC=EAC. This is an indication that the program is under control.
- EAC is also referred to as the Latest Revised Estimate (LRE) and is the total expected cost of the program as estimated by the contractor. EAC is ACWP plus the work that still must be completed (BAC-EAC). Therefore, EAC = ACWP + BAC-BCWP. When BAC-EAC is negative, the contractor is identifying an overrun. The difference between BAC and EAC is the Variance at Completion (VAC) or the contractor's prediction of the cost situation.
- Management Reserve (MR) is an amount of the total allocated budget or negotiated contract value that is withheld for management control purposes rather than designated for the accomplishment of specific work. It is designed to cover any effort that might not have been predictable when the original budget for the contractor was developed. The MR is designated for work in the scope of the contract, but out of the scope of the contractors original plan. This is not to be confused with the Government program manager's MR which is used for changes to the basic Statement of Work (SOW).

While the basic principles and concepts are very similar, there are many differences between budgeting and variance analysis procedures used in other private industries and of those used by defense contractors. The differences mainly arise because of the defense contractor's obligation to comply with C/SCSC if the contract in question meets certain thresholds. CPRs are required for R and D programs over $40 million and production contracts exceeding $160 million. The Sea Nymph Program exceeded the production contract criteria with production contracts totalling $414 million.

III. CASE STUDY AND DATA PRESENTATION

This chapter has two purposes. The first is to describe several features of the GTE Government Systems Corporation's budgeting process which may be relevant to the study of SOA advance and the cost implications of such advances. The second purpose is to present data from the Production I and Production II contracts which will be analyzed in an attempt to determine whether the internal budgeting process had any particular affect on the SOA advance exhibited in the Sea Nymph Program.

A. CASE STUDY

1. Background

The AN/WLQ-4 Sea Nymph Program represents an improvement over the AN/WLR-6 System which was also produced by GTE Government Systems Corporation. It was developed through a combined effort with the Navy because of increased capabilities of potential enemy threat . The improvement from one system to the next was estimated at approximately 100% (Ref. 1). The cost of not producing the Sea Nymph was significant. The potential existed for GTE Government Systems Corporation to lose business if the Navy contracted with a competitor. Having work in this area improves GTE Government Systems Corporation's technological capability to bid on other weapon systems in demand by the various branches of the armed services. Not producing this system had potentially serious negative consequences that may have compromised GTE Government Systems Corporation's current position in terms of sales, as the 23rd rank defense contractor for the entire DOD (Ref. 15:p. 17). Producing the Sea Nymph alleviated concern for some of these potentially negative consequences.

The Sea Nymph System is an electromagnetic warfare support measures (ESM) system whose primary mission is the collection of electromagnetic signal data in support of a submarine. The system attempts to maximize the amount of information gathering it can be tasked to accomplish, while minimizing the likelihood of counterdetection. This ESM system is a receiver system capable of electromagnetic signal intercept, analysis, and direction finding over a wide frequency range. The system receivers inputs from the communication antennas as well as the ESM antennas and is divided into five subsystems according to frequency coverage. The subsystems are operated from six different operator positions which overlap in frequency coverage.

The system performs two types of analysis: aural signal and detailed signal. In aural signal analysis, the ESM operator conducts an analysis based on the audio tone characteristics of the intercepted signals. Detailed signal analysis attempts to determine intercepted signal parameters as an aid in identifying the type and source of the signal. Mast antennas must be placed in particular positions for the system to conduct accurate direction finding.

The operator positions are dedicated to certain functions which include: communications signal intercept, intercept analysis, and direction finding of pulse modulated signals such as radars. In summary, the system provides the submarine with a rapid assessment of the electromagnetic environment by intercepting, analyzing, and determining the bearing to electromagnetic signals over a wide frequency range.

The Sea Nymph System represented a significant SOA advance over the capability of the previous ESM system it replaced, the AN/WLQ-6 System. This improvement or SOA advance was achieved in a particularly interesting manner. Interestingly, the individual components of the system did not undergo any dramatic technological enhancement. The SOA advance was accomplished by both adding

components and altering the system's configuration. The use of many components in the manufacture of the Sea Nymph System required using subcontractors to supply many of the of individual subcomponents. The SOA was advanced, but not in the traditional manner of enhancing an individual component such as an integrated circuit or a memory chip. GTE Government Systems Corporation functioned as a "system house" by working with many individual components, developing subsystems, and integrating the subsystems into an overall system.

The Sea Nymph Program, from the beginning of development through final production, consisted of eight contracts. The acquisition phase, the dollars value, and the contract type are presented in Table 4. The final two contracts, Production I and Production II, are analyzed in this study and provide the primary input for conclusions which are ultimately derived. Ideally, the development, limited production, and pilot production contracts would have been analyzed, but were not for two reasons. First, the data were not available in Cost Performance Report format because C/SCSC was not used during the early stages of the program, in the mid 1970s. Archival records at both GTE and Naval Sea Systems Command (NAVSEA) were unable to produce data at the appropriate level of detail to permit variance analysis. Secondly, there is not a specific point in time during the Sea Nymph Program when development ended and production began. Development occurred throughout all eight contracts, and thus throughout almost the entire life of the program.

2. Management Control System

When looking at a specific corporation and a program, the most logical place to begin would be to look at the organization's management control system. Numerous definitions have been offered for the term management control system. Excluding informal methods of control, four processes offered by Anthony, Dearden, and Bedford capture the

TABLE 4

AN/WLQ-4 SEA NYMPH CONTRACTS

Phase	Period	Dollars	Quantites of Systems E	N	Type of Contract
EDM	FY 76	$34.5 M	Development		CPAF/CPFF
ID	FY 77-80	$17.5 M	Development		CPAF
		$52.0 M			
LP	FY 77-78	$57.4 M	5	4	CPAF
PPI	FY 79	$57.9 M	8	3	CPAF
PPII	FY 80	$52.3 M	6	0	CPAF
PPIII	FY 81	$51.0 M	5	1	CPAF
Production I	FY 82	$102.6 M	10	6	FPI
Production II	FY 83	$92.8 M	9	6	FPI
		$414.0 M	43	20	

Note: The above figures do not include a $98.2 M spare parts package.

essence of GTE Government Systems Corporation's management control system (Ref. 12:p. 26). They are: programming, budgeting, operating and measurement, and reporting and analysis. By comparing these four processes with the basic concepts of C/SCSC, you arrive at a good overview of the corporation's management control system.

Various levels exist in GTE Government Systems Corporations. This case study looks at the Sea Nymph Program from two levels or perspectives: the overall Program Manager (PM) and the Cost Account Manager (CAM). The PM's role can be viewed as that of a decision maker, policy setter, coordinator, and reviewer. The CAM is more involved with the nuts and bolts of control. He prepares the paperwork and provides inputs for the reporting aspect of the management control system. Since the PM is a supervisory or managerial position, the CAM function provides a more detailed look at the actual operation of the management control system and the budgeting process. One concept must be understood before a discussion of the CAM and the management control system can begin. We must establish what the term budget actually means.

For purposes of this study, the budget refers to the performance measurement baseline, or simply, the baseline. The performance measurement baseline is defined as the time-phased budget plan against which contract performance is measured. It is formed by the budgets assigned to scheduled cost accounts and the applicable indirect budgets. For future efforts, not yet planned to the cost account level, the performance measurement baseline also includes budgets assigned to higher elements of the WBS, and any undistributed budgets. Undistributed budgets refer to budgets applicable to contract efforts which have not yet been identified to specific WBS elements. The performance measurement baseline is equal to the total allocated budget less any management reserve with management reserve representing a value within the negotiated contract target cost that

GTE Government Systems Corporation has decided not to initially distribute to their functional department. It is used for work that is in the scope of the contract, but out of the scope of the corporation's original plan. There is usually a strong correlation between the use the management reserve and the organization's thoroughness in developing the basic budgets which comprise the performance measurement baseline. Figure 4 is a description of the methodology employed by GTE Government Systems Corporation in establishing the baseline.

3. Establishing the Baseline

Contrary to popular belief, the baseline budget is not established when an organization submits a proposal to the Government, nor when Government acceptance is recognized when a contract is awarded. The process of establishing the baseline, and the budget, is just beginning at this point. After contract award, GTE Government Systems Corporation issues an order notice which is an internal document that provides legal authorization to start work on a given project. It is generated by the corporation's contract section and permits functional departments to begin planning.

In this planning stage, GTE Government Systems Corporation develops the program control plans. These plans take the form of four items: the Contract WBS (CWBS), the Responsibility Assignment Matrix, (RAM), Schedules, and the Statement of Work (SOW). At the time of proposal, GTE Government Systems Corporation will have developed the WBS down to the third level. This depicts a general and broad outline which is all that is needed at the time of proposal. Once the contract is awarded, a detailed WBS is needed, extending as far as the thirteenth level if necessary. This detailed WBS is referred to as the CWBS.

The RAM is a blueprint which matches tasks with responsible functional organizations within GTE Government Systems Corporation. It is broken down by cost

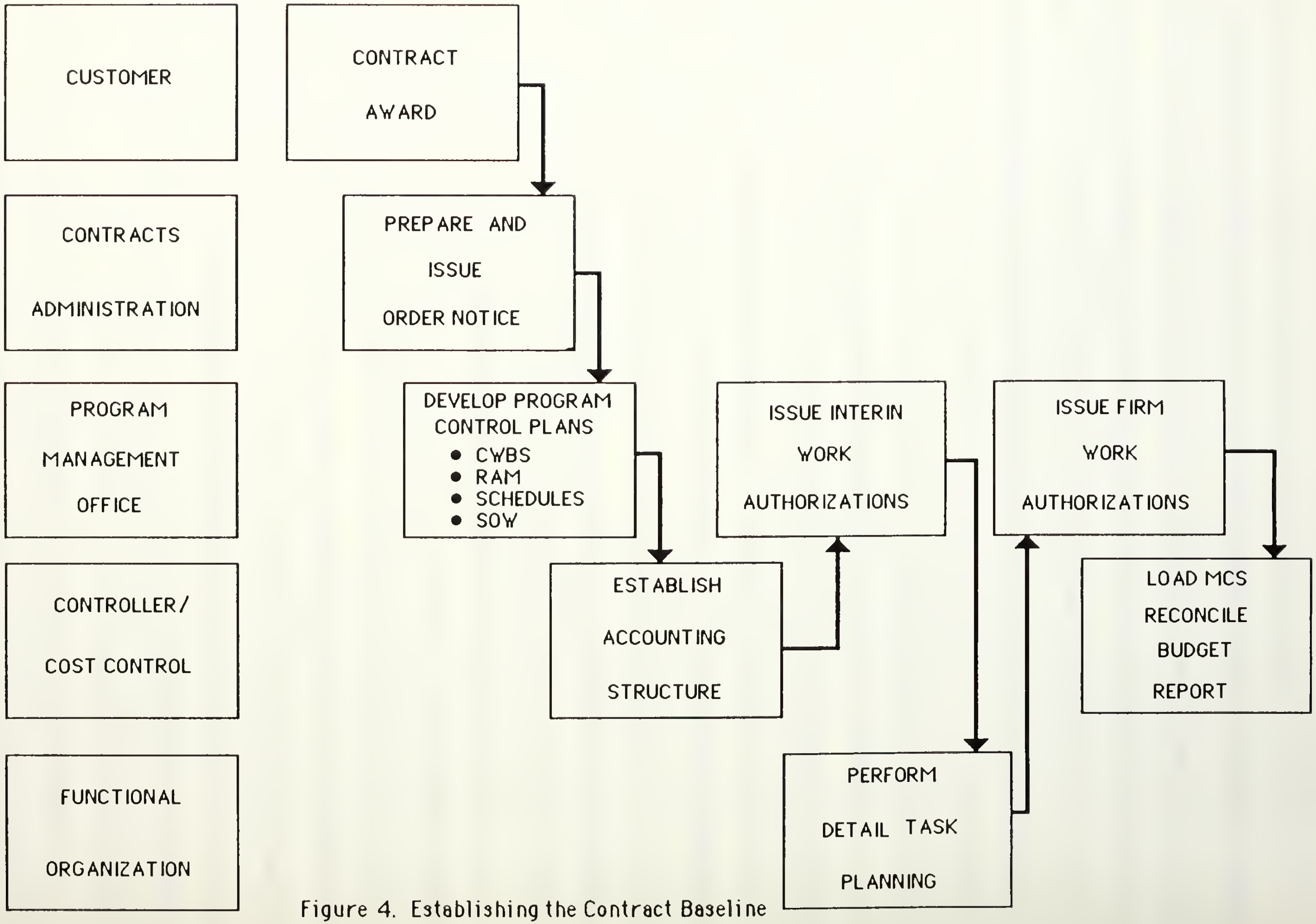


Figure 4. Establishing the Contract Baseline

account and activates the planning stage for the CAM and the functional manager. The schedules are driven by the end item delivery date. This date is supported by several lower levels of detailed schedules. The lowest level of planning schedule is achieved with the Work Package Planning Sheets (WPPS) which are discussed later.

The planning element which results from developing the program control plans is the SOW. The final SOW is reached through negotiation between the PM and the CAMs. Here they agree to a budgeted amount of money which will fund the work to be accomplished within each cost account. The CAM will receive guidance from the functional manager due to the importance of this negotiation to the corporation's budgeting process.

After the program control plans are developed, the accounting structure must be established. Here, seven digit charge numbers are assigned to each work package (cost accounts are made up of work packages). The first three digits refer to the specific contract and the last four digits identify the specific task in the work package.

Once the accounting structure is in place, interim work authorizations are issued. They cover a two month period and let the CAM use the seven digit charge number to expense the current planning effort. After the interim work authorizations are issued, the CAM submits WPPSs to support the most detailed or lowest level of the planning schedule.

Next, the firm work authorizations are issued. The PM and the CAM negotiate again, but it occurs at an aggregate level. The total budget and the SOW are matched and locked in at this point. The final step to establishing the baseline occurs when the management control system receives inputs to generate a budget report. The inputs are the WPPSs which are loaded through the data control office. The budget report distributes hours and dollars by month and year to the various CWBS levels. It is at this point that

performance measurement can begin. This first budget report is the baseline budget once an amount for the management reserve is subtracted.

4. Cost Account Manager (CAM)

The CAM's primary responsibility is the cost and schedule performance of his or her cost account. Occasionally, a CAM is responsible for more than one cost account. The cost account is the point of control for the planning, budgeting, and collecting of costs. It represents the effort to be performed by one responsible organizational manager on one contract CWBS element. When the budgets of each individual cost account are being planned, they are identified or costed in terms of labor hours and dollars, material, subcontracts, overhead, and other indirect cost dollars.

The CAM works closely with the PM's organization to perform the following tasks:

- Plan work efforts as defined by the SOW.
- Establish budgets.
- Determine manpower requirements.
- Monitor work progress in relation to schedule milestones.
- Develop estimates at completion.
- Prepare variance analysis reports. This includes an explanation of the causes, potential impact, and the corrective action required to reconcile the problem.
- Initiate and maintain all cost account documentation.
- Analyze reports designated for the CAM and generated by the management control system
- Change the plan as required. This can affect schedules and budgets. The CAM interfaces with other CAMs, functional managers, the PM, cost control personnel, and management control system analysts to effectively perform his assigned responsibilities.

The CAM must plan and control the cost account. The planning aspect is achieved with the work authorizations and the detailed schedule of job a or task assigned in a work package. The work authorization is the means by which responsibility for budget,

schedule, and task requirements is delegated from the PM to the CAM. The work authorization must be fully approved before work can start in any area. The approved process is rather detailed and requires signatures by cost control, contract administration, the PM, the CAM, and the functional manager. The work authorization provides the basis for an agreement between the tasking authority and the functional organization preforming the work. It establishes the overall schedule, the total budget, and the amount that is authorized to be expended at the cost account/work package level. The work authorization provides a SOW for what is to be accomplished and assigns responsibility for performing the defined work. The cost account is opened at this point, signifying that actual work may begin.

Work authorizations are issued only after the work to be accomplished has been defined and a firm baseline has been established. Occasionally they must be revised. The following are recognized by GTE Government Systems Corporation as legitimate reasons for modifying a work authorization:

- Adding/deleting the scope of work and budget from an existing work authorization.
- Transferring the scope of work and budget from one cost account to another.
- Issuing tasks and budgets from the undistributed budget to a cost account.
- Issuing Management reserve to a cost account.
- Including or incorporating changes in authorized funding.

The CAM also works with Work Package Planning Sheets (WPPS) and Work Package Milestone Plans (WPMP) in performing his planning responsibility. The WPPS exhibits the time-phased budget plan for all work packages and planning packages within a cost account. The CAM prepares these sheets and obtains the approval of the functional manager. While preparing the WPPS, the CAM is responsible for the following:

- Relating the work package tasks to the budget.
- Defining the overall work package schedule to include intermediate milestones.

- Identifying cumulative percentages of completion for each intermediate milestone.
- Assigning the time-phased budget
- Establishing status milestones on the WPPS for each work package.

The WPMP is a planning document which shows percentage of completion values for each measurable work package. All measurable milestones, identified on the WPPS, are listed on the WPMP and assigned a value representing the percentage of the total work package considered complete when the milestone has been achieved.

The CAM is also responsible for the preparation and submission of many other forms which provide input to the management control system. The Budget/Schedule Change Request is used in the following situations:

- To change the plans of existing work packages.
- To request a change in the scope of work, the schedule, or the budget of a work package.
- To create a new work package.

The Work Package Start/Completion Notice is used by the CAM to communicate to the cost control office the start and completion of each work package or the closure of a work package before it is completed. After submission of this report and the opening of a work package, costs can then be charged to the work package. The CAM can also submit transaction reports to update or modify the status of each work package by element of cost in terms of BCWP, EAC, revised start and stop dates, and actual start and stop dates.

The CAM plays an important role in variance analysis. The management control system generates a monthly report called the Variance Analysis Report (VAR). This report contains the current cumulative status to date for each cost account. A cost account is generally considered out of tolerance by GTE Government Systems Corporation when the percentage of the variance to budgeted cost reaches the ten percent level. Figure 5 depicts GTE Government Systems Corporation's performance measurement pyramid and provides a brief overview of the variance analysis process. In addition to the variances identified in

Figure 5, the VAR also presents an at-completion variance which exists if the budget-at-completion (BAC) varies from the estimate-at-completion (EAC) plus or minus the established tolerance limits.

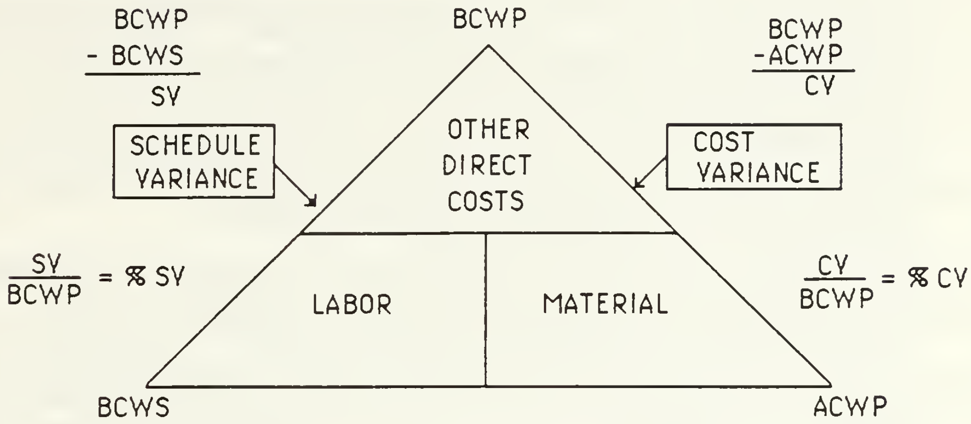


Figure 5. Performance Measurement Pyramid

When significant variances do occur, the CAM must provide a statement of the cause in terms of cost, rate, or usage. He then must assess the impact of the variance on the cost account as well as the impact of labor on the other WBS elements. The CAM then recommends and initiates the required action to remedy the situation. Often, this entails the development of a detailed plan of action for correcting the problem.

In concluding the description of the CAM's role in the management control system and budgeting process, five of the more significant reports utilized by the CAM will be discussed. The reports are: Budget Report by WBS, Monthly Performance report by WBS, Schedule Report, Performance Report, and Material Performance Summary Report.

- The Budget Report by WBS contains the time-phased budget (BCWS) planned for each cost account for the entire period of contract performance. Inputs for this report

are from the detailed planning contained in the Work Package Planning Sheets. The BCWS is summed through each level of the WBS to provide a Budget Report.

- The Monthly Performance Report by WBS presents performance measurement information for the current month, cumulative to date, and at completion periods.
- The Schedule Report presents a consolidated listing of the work packages within each cost account. The CAM uses this report to validate current work authorization schedule information and maintain compatibility with network based schedules.
- The Performance Report is a product of the Labor Tracking System (LTS). Work packages associated with the fabrication and assembly of hardware items are planned in the LTS. For manufacturing labor, standard hours are developed for each task. These standards are divided by an effectivity factor to develop the total requirement in real time hours which correspond to the planning in the management control system. The LTS produces the performance report which provides the CAM with a percent complete for each work package on a weekly basis. This percent complete becomes the BCWP percentage for the period reported.
- The Material Performance Summary Report is a product of the Material Tracking System (MTS). The production material plan is developed in the MTS. Production material planning is based upon the point at which the material is received and issued. Planned dollars reflect scheduled usage of the material and are time-phased according to the dates the material is needed. The MTS yields a percent complete for each work package based on the ratio of the average cost of material received over the average cost of material required.

This concludes the description of GTE Government Systems Corporation's budgeting process. Changes to the baseline can occur through additions to the scope of the contract via contract modification, but budget management and performance measurement are underway at this point and will continue until the final product is delivered to the customer.

B. DATA PRESENTATION

1. General

The data used in this study are taken from monthly Cost Performance Reports documenting the Production I and Production II contracts of the Sea Nymph Program. Six reports were selected from throughout each contract's life. These reports were selected to demonstrate the entire life of each contract. The only exception to this attempt at depicting each contract in its entirety is due to the fact that the contracts are currently open because

several completed systems are awaiting delivery. The cost involved are negligible and will not change the final history or conclusions reached in this study.

Both contracts are fixed price incentive fee type contracts and ran currently through a good portion of their lives. Production I called for 10 E suites and 6 N suites while Production II required 9 E suites and 6 N suites. The WBS for each contract consists of five legs. The A leg is for the prime mission production and includes all hardware preparation, testing, integration, and fabrication. Most program costs fall into this category. The B leg covers common support and includes quality assurance, rework, technical data services, and industrial engineering. The D leg accounts for system and program management. Cost categories include cost control, management control systems, travel, contract administration, reliability engineering, data management and configuration management. The F leg covers all cost data, technical data, and management data. Finally, the G leg covers the technical manuals and includes technical writing, subcontractor technical manuals, and GTE Government Systems Corporation produced technical manuals. All the work scheduled and completed in these two contracts is accounted for in one of these five contract WBS legs with the exception of indirect costs and other direct costs.

Indirect costs are those which cannot be specifically identified to a single cost element of the program, an example of which is insurance. Other direct costs refer to graphics, word processing, and printing, and more significantly, to inter-divisional transfers, materials, and subcontractor costs. These two areas of cost are substantial and their exclusion would seriously distort any type of cost or variance analysis. Obviously, a format had to be selected which included all relevant costs in each program. This left two options.

Previous discussion addressed the specific formats presented in the Cost Performance Reports. Formats 1 and 2 appeared to be likely candidates because both formats accounted for all the costs in a contract, including both direct and indirect costs. Format 1 consists of the following seven cost categories:

- Labor
- Non-Labor
- Overhead
- Division G and A
- Corporate G and A
- Cost of Money
- Obsolete Material

Format 2, which presents costs by functional categories, consists of the following categories:

• Direct Cost :	Finance Product Assurance Administration Digital Systems Lab Tactical Systems Strategic Systems Operations
• Indirect Costs:	Engineering Overhead Operations Overhead Field Overhead Procurement Overhead Division G and A

- Corporate G and A
- Cost of Money
- Obsolete Material

Format 1, which presents fewer cost categories than Format 2, was selected as the format for data presentation in this study. It is a consolidated format, but still permits the appropriate level of analysis necessary for this study. Six Format 1 Cost Performance Reports are presented for Production I and six for Production. The twelve reports are included in Appendix D.

As a reminder, the following formulas and definitions are presented:

- BCWP - ACWP = Cost Variance
- BCWP - BCWS = Schedule Variance
- BAC - EAC = AT Completion Variance
- EAC = ACWP + ETC
- % Complete = $\dfrac{\text{BCWP}}{\text{BAC}}$
- % Schedule Variance = $\dfrac{\text{Schedule Variance}}{\text{BCWS}}$
- % Cost Variance = $\dfrac{\text{Cost Variance}}{\text{BCWP}}$
- % At Completion Variance = $\dfrac{\text{Variance at Completion}}{\text{BAC}}$
- BAC = Budget at Completion
- EAC = Estimate at Completion or Latest Revised Estimate (LRE)
- BCWS = Budgeted Cost of Work Schedules
- BCW = Budgeted Cost of Work Performed
- ACWP = Actual Cost of Work Performed
- ETC = Estimate to Complete

This concludes the case study and data presentation. The next chapter consists of a detailed analysis of the Production I and Production II contracts.

IV. VARIANCE ANALYSIS

A. ASSUMPTIONS

This portion of the study analyzes the significant variances identified in the Production I and Production II contracts of the Sea Nymph Program. Several ground rules must first be established. The data presented for each period is cumulative and reflects dollar amounts that are included in previous period reports. The variances refer to what has occurred up to that point in the contract and are not limited to only the period of time covered in the report. Variances that do not meet the 10% threshold, or are not considered relevant, are not discussed. Also, if a particular variance has been previously addressed, it is not discussed again unless it is necessary to establish and identify a trend.

The following list is a summary of the Cost Performance Reports which are used as data sources:

Production I	Production II
• 28 January - 24 February 1984	28 January - 24 February 1984
• 29 September - 26 October 1984	29 September - 26 October 1984
• 26 January - 22 February 1985	26 January - 22 February 1985
• 28 September - 25 October 1985	28 September - 25 October 1985
• 27 September - 31 October 1986	1 February - 28 February 1986
• 28 February - 27 March 1987	31 January - 27 February 1987

The analysis will follow a chronological order through Production I and then Production II in an attempt to capture a complete picture of each contract. A single variance analysis performed near the end of a contract could prevent one from observing some significant aspects of cost performance which may have occurred earlier in the contract. Variances may have been significant at one point in time, were then brought back to within

standards, and removed from management's attention because they were now acceptable. These variances, even though they are within tolerance toward the end of the contract's life, could have affected costs in other areas. For example, a negative schedule variance develops and management decides to hire more personnel to ensure that the program's schedule performance improves. As this goal is achieved with additional workers, the labor cost variance could begin to deteriorate because more money is being spent on labor costs than originally anticipated.

Each Cost Performance Report analysis will begin with a program summary which is an overview of the program's status as of the date of the report. The program summary is followed with an analysis of the variances which meet the previously identified criteria for detailed review. The variances in Appendix D are very general and account for broad cost categories. The variance analysis may discuss deviations from standards which occur at a lower level, but are included in a more general cost category. The lower level variance may not be readily identifiable from the cost data in Appendix D, but is surely included in one of the categories, and in the overall cumulative cost and schedule variances.

B. PROBLEM ANALYSIS - PRODUCTION I

1. Report Period 28 Jan - 24 Feb 1984

a. Program Summary

The cumulative schedule variance reflects a favorable schedule performance of 11% and now stands at $5,641K. The primary reason for this favorable variance is the issuance of purchased material in support of ahead of schedule testing on several completed units. Circuit cards from IBM are the most significant contributors.

There were several negative contributing factors to the schedule variance even though the overall result is positive. Several components which were purchased from FEI had to be returned to the vendor for repair.

The cumulative cost variance reflected favorable performance, but the trend was expected to dissipate somewhat. The overall cost variance stood at $3,647K. GTE Government Systems Corporation felt at this point that according to past history, the cost of support functions usually begins to increase. Specifically, the cost of test support and out-of-warranty repair costs began to achieve visibility. These costs are usually front loaded into a program, but anticipated problems that do not normally occur until later stages of the program. GTE Government Systems Corporation still expected favorable performance in the cost area at completion, but stressed the need for guarded caution in allowing for unplanned and unforeseen difficulties.

Changes in the various overhead rates accounted for $267K of the $559K increase in the underrun at completion which now stands at $4,095K. An analysis of material usage (cable assemblies) accounted for another $220K of the change reflected in this underrun amount.

b. Detailed Analysis

The following factors contributed to the overall schedule variance. These variances were originally identified under the broader cost categories used in Appendix D. Only the significant factors causing the variances will be discussed.

- Several control and display units were received early from IBM and had a favorable impact.
- Additional testing equipment was being used and resulted in several ahead-of-schedule situations.
- Several switches from FEI were defective and caused negative schedule variances in several functional areas.
- Earlier testing procedures have temporarily deteriorated and caused several delays. No impact was anticipated because of the abundance of slack.

The following factors contributed to the overall cost variance. These variances fall into the cost categories presented in Appendix D and only significant contributors are discussed.

- Labor usage accounted for $820K, labor rate accounted for $65K, and material usage contributed $165K toward the overall favorable cost variance.
- A lower than budgeted manpower level was needed in the early stages of the contract and caused an initial favorable cost variance. Manpower levels then increased above that which was budgeted as personnel were added to Test and Integration. This halted and began to reduce the cost variance. The intent of an increased manpower level in Test and Integration was to increase testing efforts and reduce rework.
- Personnel were added to the Program Management function which began to reduce the favorable cost variance.

2. Report Period 30 Sep - 26 Oct 1984

a. *Program Summary*

The overall schedule was still favorable, but stood at $1,513K. BCWS and BCWP were converging which cause the schedule variance to move toward zero. Favorable performance was reflected in the production of hardware as material issues and receipts were ahead-of-schedule and caused actual production to occur earlier. Production I called for the production of technical manuals. This was behind schedule due to the late delivery of Government furnished information (GFI).

The overall cost variance increased favorably to $5,018K, but significant expenditures in the support area were anticipated to dissipate this amount. Again, test support and out-of-warranty repairs were front loaded and potential problems were anticipated to occur later in the program. Performance in the technical manual area began to degrade the favorable performance in engineering labor due to late and incomplete GFI.

The estimated underrun at completion increased to $4,870K overall, but the technical manual problem caused a reduction of $315K. A management reserve of $300K was expected to be consumed by manuals related problems.

b. Detailed Analysis

The following factors affected the overall schedule variance:

- Early material issue continued to be a prime reason for the overall favorable schedule variance, but was being offset by components which were returned to the vendor for repair.
- A negative impact on schedule variance occurred because of a change in procedure. All Sea Nymph systems were now being delivered to the submarines along with the racks in which they were to be installed. This was done in the hope of ensuring that everything would fit. As a result, rack assembly was delayed, and system testing was accelerated in order for this integration to occur.
- Failures of several components (PTTI switches and SES RF distribution units) caused negative variances in several areas. Production II units were used to support schedule performance.

The following factors affected the overall cost variance:

- Several recorders purchased form GENISCO failed and caused an over issue situation to support these failed units. As repairs took place, this negative cost variance gradually corrected itself.
- Two system test beds proved much more efficient than one and contributed to the increase in the overall favorable cost variance. GTE Government Systems Corporation's objective to improve Testing and Integration efficiency appeared to be working as positive variances were reflected in several related areas.
- Out-of-warranty repairs and test support labor contributed to a favorable cost variance because the schedule was heavily front end loaded. This situation was anticipated to reverse itself as more effort in these areas would be required later in the contract.
- Improved efficiency in Quality Assurance contributed favorably to the cost variance.
- Personnel were diverted to work temporarily outside of the Production I contract. These areas included Pilot Production III spare parts in support of fleet needs. This favorable variance was offset later in the contract.
- Late and incomplete GFI continued to cause problems. Future impact was anticipated to only reduce the favorable cost variance and it did. The technical manual effort was negotiated well into the Production I contract and is an area of concern even today.

3. **Report Period 26 Jan - 22 Feb 1985**

a. ***Program Summary***

There were two primary contributors to the negative schedule variance. BCWS and BCWP continued to converge as the hardware portion of the contract progresses and poor performance in the technical manuals area continued.

The overall cost variance continued to reflect favorable performance, but significant expenditures and a schedule extension due to the technical manuals were expected to dissipate this current positive trend. The total contract underrun stood at \$4,772K and was expected to decrease because of the application of overhead to contract labor accounts and an increase in G and A and overhead rates for 1985 and beyond. Engineering labor was expected to reduce the variance at completion by almost \$2,000K. This would place the total program underrun figure at approximately \$3,000K.

b. ***Detailed Analysis***

The following factors affected the overall schedule variance:

- Early material issues continued to support ahead-of-schedule production efforts, resulting in favorable schedule variances. Production II material was occasionally used when material for Production I was either late or defective.
- Rack, cable, and systems manuals continued to have a negative influence. Changes in personnel and word processing equipment, along with modifications due to engineering change proposals, combined for unfavorable variances.
- Manuals from VOLT were rejected and required rework. GTE Government Systems Corporation was realistically looking at a possible late delivery date for some of the manuals.

The following factors affected the overall cost variance:

- Over issues of time code generators, time code distributors, PTTI switches, and SES RFD units were unfavorable contributors to the cost variance. Excess quantities were issued because of defective units. This variance should correct itself as defective units are repaired and returned for issue. Failed GENISCO recorders and DATAMETRIC printers alone caused an unfavorable variance of \$375K.
- The use of two system test beds was again recognized for a favorable impact.

- Personnel were shifted from Production I to other contracts which were in direct support of operational fleet units. This resulted in favorable cost variances. GTE Government Systems Corporation recognized would probably impact the schedule.
- Late and incomplete GFI continued to cause unfavorable cost variances in several areas related to the technical manuals.
- A $1,375K favorable cost variance was attributed to budgeting for rework and out-of-warranty repair too early in the program. Even though a distorted picture was presented early in the program, favorable cost variances related to this area were expected to dissipate with time.

4. Report Period 28 Sep - 25 Oct 1985

a. Program Summary

Schedule performance in the technical manuals effort was the driving factor in the unfavorable $2,475K schedule variance for the total program. Of this variance, $1991K was primarily attributed to the VOLT subcontracted manuals. This required an adjustment to the delivery schedule portion of the G or technical manuals leg.

The overall cost performance continued to reflect favorable performance, but significant expenditures were anticipated in the support functions. This would dissipate some of the favorable cost variance. The overall manuals overrun alone stood at $3,325K, but the entire program underrun anticipated at completion was $2,677K.

b. Detailed Analysis

The following factor affected the overall schedule variance:

- Performance in virtually every functional area or cost category related to the technical manuals continued to deteriorate. The VOLT manuals continued to have a particularly heavy negative affect on cost variances.

The following factors affected the overall cost variance:

- Budgets that were planned too early in the program for rework and out-of-warranty repair continued to contribute favorably to cost variances in several areas. Even though underruns were anticipated in these areas, the portion of the current overall cost variance attributed to these front loaded budgets amounted to approximately $2,000K.
- Failed GENISCO recorders were again identified as the cause for an unfavorable impact on cost variance. These variances were still expected to correct themselves.

- Labor usage and labor rate variances caused by reduced staffing levels in program management and several support areas, positively influenced the overall cost variance. The schedule extension into June 1986 should cause a decline in this favorable position.
- Practically every type of technical manual contributed unfavorably to cost variances in several areas. In spite of an unfavorable variance at completion of $784K in the technical manual area, GTE Government Systems Corporation still anticipated a program wide underrun at completion of $2,677K.

5. Report Period 27 Sep - 31 Oct 1986

a. *Program Summary*

The technical manuals negative schedule variance of $1,326K was the driving factor behind the overall unfavorable schedule variance of $1,911K. The remainder of this variance was the result of claiming 99% BCWP in the material leg in order to keep these accounts open. At this point, management directed the closing of these accounts in order to eliminate the schedule variance.

The cumulative cost variance continued to reflect favorable performance. It was anticipated that the technical manuals schedule slippage, necessitating additional support function expenditures, would decrease this favorable variance. The manuals related unfavorable variance of $4,672K continued to degrade the favorable cost performance previously reported. Management did not anticipate a favorable variance at completion in the manuals area because the overrun in the G or manuals leg stood at $5,062K.

b. *Detailed Analysis*

In addition to the technical manuals situation, a portion of the overall schedule variance was attributed to paybacks owed to the Production II contract. Parts were previously borrowed in order to prevent extensive schedule slips. GTE Government Systems Corporation initiated weekly status meetings at this point to monitor the status of the manuals.

The following factors affected the overall cost variance:

- Labor usage variances continued to decline. Front end loading has been accounted for, but these variances were now declining due to continued technical manual support and the preparation of equipment needed to accommodate engineering changes.
- A modification extended the contract to December 1986 and additional costs in Program Management related functions were expected to decrease the overall favorable cost variance.
- Additional expenditures were incurred to track subcontractor performance and conduct engineering reviews. These activities had an unfavorable influence on cost variances, a trend which was expected to continue until the end of the contract.

Incurred expenses now totaled $97,580K while $100,048K had been budgeted for the amount of work which had actually been performed (BCWP). The latest revised estimate stood at $100,624K while the contract was budgeted at $102,554K. The projected underrun at completion was $1,930K.

6. Report Period 28 Feb - 27 Mar 1987

a. Program Summary

Technical manual schedule performance continued to be the driving factor behind the $951K unfavorable schedule variance for the entire program. The total program cost variance of $1,876K was being consistently eroded by the manuals' situation and by expenditures in the Program and Administrative Offices. The projected cost underrun at completion was lowered to $1,005K.

b. Detailed Analysis

The overall schedule variance showed some deterioration because the VOLT subcontracted manuals effort was terminated by GTE Government Systems Corporation and brought in-house. Estimate at completion were changed to reflect a June 1987 delivery date. As a result of this extension, all BCWP claims submitted from this point forward would reduce the favorable schedule variance by the amount of the claim because GTE Government Systems Corporation was accruing no BCWS.

The effort to bring the VOLT contract for manuals in-house had an unfavorable affect on the overall cost variance. It appeared that GTE Government Systems Corporation was attempting to cut their losses at this point. The cost of this effort was not offset in full by the deobligated subcontractor funds. Expenditures in the B leg for rework and out-of-warranty repair were underrun significantly and contributed $278K favorably to the overall cost variance. Efforts for testing and evaluation procedures were underrun and also contributed favorably.

With over 98% of the estimated costs already incurred, and completed work approximated at over 98%, the contract was at a stage where conclusions concerning final coat outcomes could be drawn with a very high degree of certainty. The technical manuals situation caused unanticipated costs, but GTE Government Systems Corporation felt they had control of the situation even though this area would remain open for some time.

C. PROBLEM ANALYSIS - PRODUCTION II

1. Report Period 28 Jan - 24 Feb 1984

a. Program Summary

The overall schedule variance reflected an unfavorable position primarily due to late vendor deliveries. The variance at completion stood at $2,832K as a result of changes to the indirect rates for 1984 and beyond. A management reserve of $2,930K existed, $900K of which GTE Government Systems Corporation expected to consume prior to the end of the contract. This estimate reflected the anticipated impact of residual materials. An estimate for obsolete material was also budgeted at $300K.

b. *Detailed Analysis*

The following factors affected the overall schedule variance:

- Defective circuit boards were received from CIRTEC and INTERCIRCUITS and resulted in a prime mission product schedule variance of $593K. GTE Government Systems Corporation Engineering and Quality Assurance teams became involved to stabilize the situation and then second sources were identified.
- Temporary capacity limitations in the fabrication shops were causing a backlog in kitting and assembly.
- Evaluation of several key components was proceeding with higher acceptance rates than during the Production I contract. GTE Government Systems Corporation characterized this phenomenon as a learning curve improvement. By identifying problem components early, the testing and integration stages were less likely to be delayed.

With approximately 6% of the work complete, and incurred expenses at approximately 6% of amount that would eventually be spent, the overall cost variance was not yet at a level which received extensive managerial attention.

2. Report Period 29 Sep - 26 Oct 1984

a. *Programing Summary*

The overall schedule variance increased unfavorably due to a schedule slip which was caused by delays in the receipt of several circuit card assemblies. The effect of these delays was expected to have repercussions in assembly at the next higher level and it did. TEXAS INSTURMENTS also had problems with defective integrated circuits which had an unfavorable effect on later assembly efforts. This negative variance is decreasing due to overtime, but the effects were not expected to diminish significantly for several months. Since the Production I contract was nearing completion in the hardware assembly area, available capacity was going to be dedicated to the recovery of the Production II contract without any conflict from other commitments.

The baseline schedule was constructed with levels of slack built into it to allow the resolution of problems without delaying delivery schedules. At this point, the

Program Office forecasted that all deliveries would be on or ahead of schedule with the use of some slack.

The variance at completion reflected an underrun of $3,478K. Its main components were the management reserve less its estimate and an underrun due to indirect rates.

b. Detailed Analysis

The following factors affected the overall schedule variance:

- The problem referred to in previous reports with circuit card assemblies was starting to exhibit a recovery, but the monetary impact of the recovery at the lower level assemblies was being more than offset by the effect of the delay on the next higher assemblies which are of a much higher dollar magnitude.
- Improper testing of integrated circuits by TEXAS INSTURMENTS also affected next higher assemblies and had an unfavorable impact on the schedule variances in several areas.
- Log amplifiers were overdue from VARIAN and added to the schedule variance. Additional amplifiers were then ordered from an alternate source for schedule protection. No long term problems were anticipated because significant slack had been built into the schedule.
- Several discs and printers were issued ahead of schedule for Engineering evaluation and caused a favorable schedule variance in the purchased prime mission hardware area. GTE Government Systems Corporation attempted to do this at every opportunity to enable the early identification of problem units and eliminate delays during integration efforts and to allow for the effective utilization of warranties.
- Several items requiring fabrication and assembly, primarily IDR brackets and backplanes, were behind schedule and caused the delay of next higher level assembly. Many subcontract items such as power supplies, heat exchangers, and centrifugal fans are available in stock, but cannot be used yet due to these delays.
- GTE Government Systems Corporation previously decided to ship the actual systems and their racks to the submarines together. This change in policy occurred so that the system and the rack could be fitted together and placed in the submarine rather than performing this function in the submarine after full house. Since rack deliveries were scheduled ahead of system deliveries, a combination of delay in the rack deliveries and an acceleration of systems availability was necessary to accommodate the integration of the two. This affected the overall schedule variance, but no impact was anticipated on contractual delivery dates because of slack.
- A PTTI switch was issued late and another was transferred to the Production I contract for system support. This caused an unfavorable schedule variance.

- Production emphasis was shifted from Production II to Production I to complete the final Production I system. This unfavorable variance was expected to stabilize and improve.

The following factors affected the overall cost variance:

- Additional effort was required in an attempt to recover the negative schedule variance previously discussed. The use of overtime and less experienced personnel was not anticipated and caused costs to exceed the budget.
- Price variances on material caused cost variances to increase unfavorably in several functional areas.
- Non-recurring costs associated with the selection of second source vendors resulted in additional overhead which was not budgeted for.

3. Report Period 26 Jan - 22 Feb 1985

a. Program Summary

The TEXAS INSTRUMENTS problem was resolved, but the negative impact on the overall schedule variance will not dissipate for several months. Several engineering change proposals were approved and would change the baseline. Approximately 30% of the contract was complete at this time.

b. Detailed Analysis

The following factors affected the overall schedule variance:

- The previously identified problem with CIRTEC and INTERCIRCUITS was almost corrected at this time and GTE Government Systems Corporation was receiving many circuit card assemblies. Labor then became a problem and mechanical assembly fell behind schedule because of the influx of assemblies. The proposed correction plan entailed using contract labor, increasing the use of overtime, and using outside sources to accomplish work.
- The TEXAS INSTRUMENTS problem with the improper testing of integrated circuits continued to delay next higher level assemblies and caused an increase in unfavorable schedule variances.
- Late deliveries by VARIAN also posed additional schedule variance problems.
- GTE Government Systems Corporation was still attempting to synchronize the production of the racks and the complete systems. Progress was being made, but still contributed to the unfavorable schedule variance.
- The early issue of time code distributors and generators, PTTI switches, and SES RFD units contributed favorably to the overall schedule variance.

- Emphasis on Production II was re-established, but a full recovery was not expected for several months. Schedule variances in the assembly area were expected to gradually improve.
- Early issues enabled the early detection of problem units in several functional areas and allowed for the effective utilization of vendor warranties and assured schedule integrity.

The following factors affected the overall cost variance:

- Efforts to catch up on the negative schedule variance indirectly caused the cost variance to increase unfavorably. The use of overtime and less experienced personnel were the primary reasons.
- In the hardware preparation area, labor usage and labor rate variances attributed to a negative cost variance. Several overruns in material categories caused similar unfavorable results.

4. Report Period 28 Sep - 25 Oct 1985

a. *Program Summary*

There was considerable deterioration in the overall schedule variance. Slips in IBM's delivery schedule resulted in shortages of display keyboards, data indicators, display controls, and display indicators. High failure rates of DATAMETRIC and DDC components also contributed unfavorably to the schedule variance. Built in schedule slack was still preventing delivery date delays.

Higher test yields and increased efficiency of test personnel contributed substantially to the estimated underrun at completion of $3,837K.

b. *Detailed Analysis*

The following factors affected the overall schedule variance:

- Received material was not being issued because of behind schedule positions in the assembly of several components. An initial behind schedule situation appeared to only make the behind positions in related functional areas worse.
- Slight improvement in the overall schedule variance was anticipated as defective units, which were returned to the vendor for repair, were being returned for a second time.
- Altering the system and rack assembly schedule to achieve simultaneous delivery continued to reflect unfavorably on the overall schedule variance.

- IBM components were large dollar value items and behind schedule issues caused variance swings of a large magnitude.

The following factors affected the overall cost variance:

- Efforts required to catch up on the negative schedule variance continued to indirectly influence the cost variances in several areas, and as a result, affected the overall cost variance.
- Additional inspection points were added to improve the quality in the final product. While this procedure caused initial overruns in several assembly areas, the additional cost was expected to be more than offset by savings from improved test yields. This eventually occurred.
- Improved testing procedures reduced the number of test hours used. This factor contributed favorably to both the overall cost variance and the anticipated underrun at completion.
- Several levels of effort accounts were running behind schedule in Sustaining Engineering and resulted in a labor usage variance. Money was not being expended when it should have been and caused a cost variance which was expected to diminish.
- A change in the frequency and location of Program Reviews caused the travel account to be less than planned.
- Budgets for rework and out-of-warranty repairs were planned too early in the program. As costs were accumulated in these areas, the positive cost variances were expected to recede.

At this point in time, approximately 62% of the project was complete. This also included several approved engineering change proposals which increased the original baseline of $84,750K to $89,841K.

5. Report Period 1 Feb - 28 Feb 1986

a. Program Summary

The IBM equipment account continued to reflect unfavorably on the overall schedule variance. Some recovery was detected in the earlier delays caused by the TEXAS INSTURMENTS components. VARIAN and RHG units had problems passing test which delayed several assemblies, but GTE Government Systems Corporation was procuring extra amplifiers to provide schedule protection.

The management reserve stood at $3,158K and GTE Government Systems Corporation expected to consume $1,900K of it before the end of the contract. The

$1,900K figure reflected the expected impact of residual materials and the anticipated impact of adjustments to estimates which normally occur. An estimate for obsolete material of $300K was also included.

The variance at completion reflected an underrun of $3,332K. The main components were still the management reserve less its estimate and an underrun due to indirect rates. Increased efficiency of test personnel and improved testing methods also contributed to the program underrun.

b. Detailed Analysis

The following factors affected the overall schedule variance:

- Integration of the rack and system delivery schedules continued to contribute unfavorably to the overall schedule variance. Slack will prevent any impact on contractual delivery dates.
- An assortment of defective units caused delays in next higher level assembly and increased the unfavorable schedule variance.
- Schedule slips in IBM deliveries resulted in shortages and had a significant impact because of the dollar magnitude of the systems.

The following factors affected the overall cost variance:

- Most unfavorable material variances were expected to be recovered when the unused portion of issued bulk material is returned to stores.
- The Unit Test function continued its favorable performance due to increased inspection points, improved testing methods, and increased efficiency of test personnel.
- Accelerated schedules in Systems Integration and Acceptance reduced the number of hours required for each E and N unit below the originally budgeted amount, resulting in a positive cost variance.
- Level of effort accounts continued to run behind schedule, contributing positively to several cost variances.

6. Report Period 31 Jan - 27 Feb 1987

a. Program Summary

The overall unfavorable variance schedule stood at $239K which reflected a significant improvement over the previous year. The improvement was a reflection of time more than anything else. This variance will continue to dissipate as accounts are closed.

The variance at completion reflects a program underrun of $5,473K. Positive test results continued and several level of effort accounts remained behind schedule resulting in an overall positive labor usage variance.

b. Detailed Analysis

The primary factor contributing to the overall schedule variance is a result of only claiming 99% completion in order to keep the accounts open.

The following factors affected the overall cost variance:

- Several outstanding commitments existed. Variances in this category will decline as the commitments are paid.
- Several material price variances and unanticipated conduit rework efforts contributed unfavorably to the overall cost variance.
- Accelerated schedules continued to reduce the required number of integration and acceptance hours and reflected favorably on the cost variance. This factor also contributed heavily to the favorable variance at completion.
- Level of effort accounts continued to run behind schedule and resulted in a positive labor usage variance.

Actual production in both contracts has been completed. Production I remains open primarily to manage the final effort for the technical manuals. Production II remains open for administrative and bookkeeping purposes. The next chapter summarizes the variances which were determined relevant to this study.

V. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

The primary purpose of this study was to determine if GTE Government Systems Corporation's internal budgeting process provided effective control over differences between estimated development and initial production costs and the costs which were actually incurred in the Sea Nymph Program. The focus of this effort was to observe whether the results obtained from comparing budgeted and actual costs could be linked to the fact that the SOA was being advanced in this program. The methodology employed in performing this research was case study. Subsidiary areas of research examined the following:

- GTE Government Systems Corporation's budgeting process.
- GTE Government Systems Corporation's I R & D efforts.
- Tracking the Sea Nymph Program through the budgeting process.
- Ability of the budgeting process to successfully estimate costs.

Several conclusions were reached early in the study which somewhat altered the research effort. First, GTE Government Systems Corporation performs an extensive amount of I R & D. The effort performed during the Sea Nymph Program occurred under contract, so R & D took place rather than I R & D. The program's first contract, referred to as the Engineering Development Model, did not require any research, but immediately began at the development stage. GTE Government Systems Corporation and the Navy were obligated under a cost plus award fee contract during this effort. As a result, it was determined that analysis of GTE Government Systems Corporation's I R & D efforts would not provide a significant amount of insight into the primary purpose of this study; to

compare estimated and actual costs and determine if the reasons for any differences had any correlation to SOA advance.

The second conclusion reached at the outset was that development and initial production contracts would be extremely difficult candidates to analyze. Costs were distorted for several reasons. First, the cost history of some of the initial contracts was not readily available or not available at the level of detail needed to conduct a thorough analysis. Second, the Navy's requests for expedited development and delivery increased costs, but these increases were not applicable to SOA advance. Third, the operational schedules of the submarines caused the original Sea Nymph installation schedule to change. This affected initial production costs, but to a lesser extent than the Navy's efforts to expedite the delivery schedule. Finally, technical problems were carried over from the Engineering Development Model contract to the Initial Development contract to the Limited Production contract through the Prototype contracts. This made identifying specific problems with specific costs extremely difficult and quantifying these costs almost impossible. The primary problem though was the unavailability of cost data at the level of detail needed to conduct variance analysis. Development and production costs are integrated and cannot be readily truncated into clearly segregated categories. There was a high degree of concurrent development and production during the Sea Nymph Program.

As a result, the final two contracts of the program were identified as subjects for the study. This conclusion was reached in conjunction with Mr. Stan Swales of GTE Government Systems Corporation and the Sea Nymph Program Manager. It was thought that the Production I and Production II contracts would provide an appropriate amount of historical cost data to perform the study as defined in the primary and subsidiary research questions. The Cost/Schedule Control Systems Criteria ensured the data was also available at the necessary level of detail.

The third conclusion that was reached early in the case study dealt with manner in which the SOA was advanced in the Sea Nymph Program. Rather than advancing the SOA of an individual component, the SOA was advanced by adding new designs and components. The SOA was not advanced with new technologies, but by developing new designs with components that were either off-the-shelf or approaching the SOA. All designs used in both the development and production fell into one of two categories as 70%-80% of the designs used in the Sea Nymph Program were previously in existence, and 20%-30% were new. The SOA was advanced with the use of new designs and added equipment rather than by advancing the technology of a component.

GTE Government Systems Corporation was the "systems house" in this particular example of SOA advance. Obviously they were responsible to the Government for the entire program as the prime contractor. But GTE Government Systems Corporation had several functional responsibilities which demonstrated their particular expertise in this type of program. Besides creating new designs and developing a new system, GTE Government Systems Corporation had to ensure that integration occurred on two levels. First, the individual piece parts of the system had to be integrated with each other in order for the system to operate as intended. Secondly, integration had to occur between the system and the submarine. The system had to be compatible with the submarine's power supplies, ventilation, and designated noise levels. GTE Government Systems Corporation performed these functions effectively. With these initial conclusions presented, a discussion of the research questions and general conclusions follow.

B. CONCLUSIONS

GTE Government Systems Corporation's budgeting process appeared to be effective at controlling costs during the Production I and II contracts. The bottoms-up or engineered

cost estimating methodology was also effective during the proposal process of these contracts at providing the budgeting organization with an initial starting figure. The effectiveness of GTE Government Systems Corporation's parametric cost model cannot be readily evaluated because the Sea Nymph Program served as the data source for the development of this model. The parametric cost model was used during the later contracts as a check of the engineered estimates.

GTE Government Systems Corporation's estimating efforts were effective for at least two reasons. First, a lower level of uncertainty existed for this particular SOA advance because existing components were used to manufacture the system. Second, the Production I and II contracts benefitted from the learning curve experienced during the first six contracts of the program. The estimated costs of the Limited Production and Pilot Production I contracts were underestimated by approximately 30% while the actual costs for Production I and Production II were being projected at 5% less than estimated costs. As the program progressed, estimating efforts became more accurate.

GTE Government Systems Corporation's structured organization which estimated the budget or the baseline was effective at estimating costs for the Production I and II contracts as demonstrated by the projected accuracy figure of approximately 5%. The proposal, negotiating, and budgeting processes appeared well integrated with the internal management control system and one function was smoothly followed by the next. This case study discussed the key aspects of the budgeting process, as specified in a subsidiary research question, and attempted to analyze the interaction between the key players. Although this was accomplished, observations of this interaction could not identify any significant relationship with SOA advance.

The primary research question attempted to determine if the budgeting process contributed to the differences between estimated development and initial production costs

and the costs which were actually incurred. Analysis then attempted to reveal if these differences could be associated with the fact that the SOA was advanced in this program.

The 30% underestimate in several development and pilot production contracts can be partially attributed to the SOA advance. SOA advance in any program reflects a higher degree of uncertainty than would normally be expected. Actually, GTE Government Systems Corporation was faced with a lesser degree of uncertainty because they dealt with existing technology. In other words, the 30% underestimate figure is conservative compared to what it could have been. The accuracy of the Production I and II contracts cannot be attributed to a mastery of estimating the costs associated with SOA advance. The greatly improved accuracy can, to some degree, be attributed to lessons learned during the development contracts and the decline in uncertainty as new designs were tested and produced.

The budgeting process was a cohesive and structured effort, and cannot be identified as a reason for differences between estimated and actual costs. Naturally, there will always be some disagreement between these costs, but the differences were not significant in the Production I and II contracts. In the earlier development and production contracts, the budgeting process was effective. A possible reason for differences between estimated and actual costs in these earlier contracts could be that the engineered estimate, used in the development of the budget, did not take complexity and technology factors into consideration.

The following paragraphs address general conclusions which were indirectly related to the research questions.

The primary cause of any schedule delay during the Production I and II contracts was the inability of subcontractors to supply material when it was required. GTE Government Systems Corporation requested assistance from the Department of Commerce for late

vendor deliveries. The Department of Commerce expedited deliveries and prioritized shipments to Government activities, ensuring more important programs received the material first.

GTE Government Systems Corporation had the foresight to build a significant amount of slack into the Production I and II schedules. Possibly, experience from earlier development and pilot production contracts caused them to do this. This initiative proved effective, and kept delivery schedules on track, with the exception of the technical manuals.

Improving test methods was a profitable undertaking for GTE Government Systems Corporation. New software and automated testing methods improved efficiency and increased yields on systems completing this stage. Additional quality assurance test points also proved profitable. Additional costs in quality assurance were more than offset by the savings incurred in test and integration.

The technical manuals presented problems to GTE Government Systems Corporation. Subcontractors did not perform adequately and one was even released well into the contract. The Navy placed the technical manuals second in importance to system hardware and was also slow in providing GFI. The manuals were delivered well after systems had been placed in the fleet for operational use. Needless to say, this caused severe problems. GTE Government Systems Corporation was extremely aggressive in estimating technical manual costs and developing schedules.

The combination of poor performance on the part of the subcontractors, the Government, and GTE Government Systems Corporation lead to integrated logistic problems which were resolved after much cost and frustration.

Front loading rework and out-of-warranty costs into the time-phased budget produced initial variances which were eventually reconciled. Improvement in the testing and quality assurance areas contributed to the variances, as did the extension of warranties. Significant

variances appeared during the contract, but were within tolerance near the end of the contract.

Material delivery delays had a negative affect on scheduled work in two ways. First, immediate work was delayed. This then caused a delay at the next higher level of assembly, resulting in a snowball effect as each level of work was influenced. Second, when the material was received, production capacity was not great enough to accommodate all the necessary work. As a result, additional delays were experienced.

Overall, costs were controlled effectively by the budgeting process and GTE Government Systems Corporation was able to obtain their target profit as identified in the fixed price incentive fee contract. In addition, they were also able to share in additional profits with the Government by successfully controlling costs.

C. RECOMMENDATIONS

This discussion is divided into two sections. The first addresses recommendations for GTE Government Systems Corporation. The second group of recommendations addresses managing SOA advance and a DOD budgeting implication, and then concludes with additional areas of research.

1. GTE Government Systems Corporation Recommendations

As a result of substandard vendor performance, establish a tracking mechanism which evaluates and documents this performance. If possible, use alternative sources for both material and labor. Secondary sources could be identified even when the primary source is performing satisfactorily.

The bottoms-up or engineered cost estimating method is GTE Government Systems Corporation's primary means of estimating, and their parametric cost model is used as a check. The parametric cost model includes factors for technology and complexity

while the engineered approach does not. The accuracy of the engineered approach could be improved by including some type of additional cost factor when new designs are being developed. New designs for a "systems house" would constitute SOA advance. Ideally, the parametric cost model will eventually gain wider acceptance as it is further validated and provide greater accuracy as a technology factor is included. A discussion of parametric cost models was included in Chapter 2, while technology factors and their application to parametric cost models was addressed under the Unmanned Spacecraft Model in Chapter 2. Efforts on this direction may improve the 30% underestimate situation on Limited Production and Pilot Production I.

More accurate estimates could be developed earlier in a program's life and learning curve improvements would not have to be the sole means of achieving greater accuracy.

2. SOA Advance Recommendations

Measuring SOA advance is dependent upon the appropriate data. Dr. Dodson has referred to the data collection effort as 90% of the problem in cost analysis. The collected data should include physical or performance characteristics of the system. Armed with this information, SOA advance measurement can be attempted. Obtaining data is the problem. This situation could be improved within private industry and at the DOD level. A joint service effort, for example, could be established to create a data base to provide the characteristics necessary for SOA advance measurement. Cost data is useful to monetarily quantify and validate the measurement of SOA advance, but is not in itself an appropriate means of measurement. Private industry could also enter into a similar venture to develop a data base which would facilitate SOA measurement.

Additional test and quality assurance efforts may be beneficial in the development and production phase of program which advances the SOA. GTE Government Systems

Corporation benefitted from this approach and similar programs characterized by SOA advance may be able to derive the same benefits.

Often, it is necessary to develop cost estimates for systems before the technology needed to produce and operate the system is available. The cost of developing and demonstrating this needed technology should be separated from the aggregate cost estimate. This decoupling effort will permit the focus of attention to be placed on the cost assumptions of technology development. This concept requires the costs of technology advance to be segregated from the R and D budget and may provide additional insight into measuring SOA advance.

3. DOD Budgeting Implication

<u>The current annual budgeting process within DOD for R and D and procurement is often criticized by defense contractors for interrupting a program's funding and causing additional costs.</u> This explanation was offered as a possible reason for increased costs during the Sea Nymph Program. These additional costs, in some situations, could be additions to the cost associated with SOA advance. Milestone budgets are a possible method of lessening this problem and may indirectly reduce the costs associated with SOA advance. Milestone budgeting provides program funding between the major milestones of an acquisition program. Funding is provided on an annual basis presently. Under milestone budgeting, program funding between milestones often exceeds one year. If properly implemented, this could add stability to the individual program and permit longer ranged planning.

4. Additional Areas of Research

<u>Conduct a study to determine how cost researchers intend to estimate the cost of the new technology in electronics.</u> Specifically, what new developments in electronics are being applied to weapon systems? The intent of this study is to develop a focus for

NAVSEA cost research efforts. The first step is to survey electronics corporations and determine exactly what the new technologies are. Secondly, the cost research and analysis organizations of these same corporations would be surveyed to determine how they intend on generating cost estimates for these new technologies. NAVSEA wants to know the areas of cost estimating they should pursue not only to stay current, but to remain at the forefront of the cost estimating discipline.

Conduct follow-on studies to identify factors which influence the costs associated with advancing SOA. Such studies could be patterned after this effort, but development costs should be analyzed.

Determine if the application of Expert Systems technology can contribute to the measurement of SOA advance and cost estimating.

APPENDIX A LIST OF SUBCONTRACTORS

- AIKEN
- ALMOND
- ARI
- CIRTEC
- DATAMETRICS
- DDC
- EATON
- FEI
- FLUKE
- FRANK HILL
- GENISCO
- IBM
- INTERCIRCUITS
- LANGLEY
- MICROPHASE
- MITEQ
- OMNI STECTRA
- RACAL
- SANDERS
- TELEDYNE
- TEXAS INSTRUMENTS
- TRAK
- VARIAN

APPENDIX B C/SCSC CRITERIA

The contractors' management control systems will include policies, procedures, and methods are designed to ensure that they will accomplish the following:

a. Organization

(1) Define all authorized work and related resources to meet the requirements of the contract, using the framework of the Control Work Breakdown Structure (CWBS).

(2) Identify the internal organizational elements and the major subcontractors responsible for accomplishing the authorized work.

(3) Provide for the integration of the contractor's planning, scheduling, budgeting, work authorization and cost accumulation systems with each other, the CWBS, and the organizational structure.

(4) Identify the managerial positions responsible for controlling overhead(indirect costs).

(5) Provide for integration of the CWBS with the contractor's functional organizational structure in a manner that permits cost and schedule performance measurement for CWBS and organizational elements.

b. Planning and Budgeting

(1) Schedule the authorized work in a manner which describes the sequence of work and identifies the significant task interdependencies required to meet the development, production and delivery requirements of the contracts.

(2) Identify physical products, milestones, technical performance goals, or other indicators that will be used to measure output.

(3) Establish and maintain a time-phased budget baseline at the cost account level against which contract performance can be measured. Initial budgets established for this purpose will be based on the negotiated target cost. Any other amount used for performance measurement purposes must be formally recognized by both the contractor and the Government.

(4) Establish budgets for all authorized work with separate identification of cost elements (labor, material, etc.).

(5) To the extent the authorized work can be identified in discrete, short-span work packages, establish budgets for this work in terms of dollars, hours, or other measurable units. Where the entire cost account cannot be subdivided into detailed packages, identify the far term effect in larger planning packages for budget and scheduling purposes.

(6) Provide that the sum of all work package budgets, plus planning package budgets within a cost account equals the cost account budget.

(7) Identify relationships of budgets or standards in underlying work authorizations systems to budgets for work packages.

(8) Identify and control level of effort activity by time-phased budgets established for this purpose. Only that effort which cannot be identified as discrete, short-span work packages or apportioned effort will be classed as level of effort.

(9) Establish overhead budgets for the total costs of each significant organizational component whose expenses will become indirect costs. Reflect in the contract budgets at the appropriate level the amounts in overhead pools that will be allocated to the contract as indirect costs.

(10) Identify management reserves and undistributed budget.

(11) Provide that the contract target cost plus the estimated cost of authorized but unpriced work is reconciled with the sum of all internal contract budgets and management reserves.

c. Accounting

(1) Record direct costs on an applied or other acceptable basis in a formal system that is controlled by the general books of account.

(2) Summarize direct costs from the cost accounts into the WBS without allocation of a single cost account to two or more WBS elements.

(3) Summarize direct costs from the cost accounts into the contractor's functional organizational elements without allocation of a single cost account to two or more organizational elements.

(4) Record all indirect costs which will be allocated to the contract.

(5) Identify the bases for allocating the cost of apportioned effort.

(6) Identify unit costs, equivalent unit costs, or lot costs as applicable.

(7) The contractor's material accounting system will provide for:

(a) Accurate cost accumulation and assignment of costs to cost accounts in a manner consistent with the budgets using acceptable recognized, costing techniques.

(b) Determination of price variances by comparing planned verses actual commitments.

(c) Cost performance measurement at the point in time most suitable for the category of material involved, but no earlier than the time of actual receipt of material.

(d) Determination of cost variances attributed to the excess usage of material.

(e) Determination of unit or lot costs when applicable.

(f) Full accountability for all material purchased for the contract, including the residual inventory.

d. Analysis

(1) Identify at the cost account level on a monthly basis using data from, or reconcilable with, the accounting system:

(a) Budgeted cost for work scheduled and budgeted cost for work performance.

(b) Budgeted cost for work performed and applied (actual where appropriate) direct costs for the same work.

(c) Variances resulting from the above comparisons classified in terms of labor, material, or other appropriate elements together with the reasons for significant variances.

(2) Identify on a monthly basis, in the detail needed by management for effective control, budgeted indirect costs, actual indirect costs, and variances along with the reasons.

(3) Summarize the data elements and associated variances listed in (1) and (2) above through the contractor organization and WBS to the reporting level specified in the reasons.

(4) Identify significant differences on a monthly basis between planned and actual accomplishment and the reasons.

(5) Identify managerial actions taken as a result of criteria items (1) through (4) above.

(6) Based on performance to date and on estimates of future conditions, develop revised estimates of cost at completion for WBS elements identified in the contract and compare these with the contract budget base and the latest statement of funds requirements reported to the Government.

APPENDIX C DESCRIPTION OF CONTRACT TYPES

- Firm Fixed Price (FFP) - A firm fixed price contract is used when the procuring agency has a definitive design or performance specification available and where a fair and reasonable price can be established at the beginning. The best use of the FFP is when the item is standard or modified commercial or military "off-the-shelf" items or when prior purchasing experience of the same or similar items or services have been procured under competitive circumstances. Valid cost estimates or pricing data is often the driving element in FFP contracts as the contractor is assuming all financial risk. FFP contracts are not subject to adjustments regardless of the actual costs experienced by the contractor. They are preferred over all other contracts types and usually do not require cost reporting. Schedule performance is required.

- Fixed Price with Economic Price Adjustment (FP-EPA) - The FP-EPA type of contract is very similar to the FFP contract. The basic difference is the ability to adjust the price during the performance based on a pre-arranged agreement. It is used where there is an unstable material or labor market. An example would be an item of precious metal which are subject to wide fluctuations. Another use would be during inflationary periods where the labor rate cannot be firmly estimated because of union inflation agreements. An FP-EPA could also adjust downward if predicted inflation does not occur. It reduces the cost risk to the contractor and could enable the Government to negotiate a lower price on the effort. This type of contract has the same applicability as the FFP and is preferred over any cost reimbursement type contract.

- Fixed Price Incentive Firm (FPIF) - This is one of the more popular type of contracts in systems acquisition. It is not truly "Fixed Price" as the actual end price could be as high as the "contract ceiling" and could be as low as the "target cost." The interesting feature of the FPIF contract is that it always has a profit sharing formula negotiated in the basic contract. This provides the contractor with an incentive to do the effort, if possible, under the target cost as they will share in the savings. If, however, the effort costs more than the target cost, the contractor shares in the over target amount to the pre-arranged agreement. Usually the contractor's share comes out of the profit and fee. The sharing formula tends to be designed so that profit to the contractor in the case of the contract going to ceiling price is zero or as low as 2%. Costs above the ceiling are not totally absorbed by the contractor. This type of contract permits incentivizing of costs, performance, quality and delivery schedule. The contractor has a degree of responsibility and a positive profit incentive. Cost reporting in some detail is always required with FPI contracts and considerable Government involvement in ensuring that the contractor's accounting system is accurate, is paramount.

- Fixed Price Incentive Successive (FPIS) - This type of contract is very similar to the FPIP contract with only a few notable exceptions. The FPIS is used when a FPIF is desired but when the vagary of the program does not permit final target cost or final profit formula to be negotiated at the start of the program. In this case an initial target cost and profit targets are negotiated into the contract. During the performance, certain pre-stated production points are reached and negotiations take place to determine final profit formula. All of the FPIF definitions apply.

- Fixed Price with Redetermination (FPR) - There are two types of FPR contracts, persecutive and retroactive. Retroactive is the least used as it is for R & D contracts of less than $100,000 where the contract is so small or the period of performance os so short as to preclude using any other type of contract. A ceiling price is negotiated into original contract and a final price is redetermined after completion.

  The prospective type used more often and is designed to handle quantity production when the final quantity for the period of performance is not known. An initial quanti-Firm Fixed price, as quantities increase (or decrease), the contract price is redetermine. Generally used for items such as engines,standard electronic components and the like, it permits quantity changes without re-advertising the contract during the performance period. Some cost data can be obtained on this type of contract, and the contractor must have an adequate accounting system.

- Cost Plus Award Fee (CPAF) - Cost reimbursement type of contracts generally create the greatest risk on the Government. The award fee type of contract permits subjective evaluation of the contractor's performance by the contracting officer at specified points in the contract for award purposes. The contract must contain clear and unambiguous evaluation criteria to be used in determining the award fee. The fee or a portion of it can be earned based on performance, ingenuity and cost effectiveness.

  Usually an evaluation board recommends the award which is limited to 15% of research and development effort and 10% of production and service effort. The determination of the amount of the award fee is not is not subject to the disputes clause of the contract. The CPAF contract requires the contractor to have an adequate accounting system and if possible a performance measurement and reporting system. It is a costly contract to administer but does incentivize the contractor in s significant manner. Cost data reporting is extremely useful for this contract type.

- Cost Plus Incentive Fee (CPIF) - This type of contract is frequently used for major systems development where there is a high probability of success and positive profit incentives can be negotiated. CPIF contracts have a formula for determining the fee and the performance incentive points (usually cost) in the basic contract. The contract must contain target cost, target fee, minimum and maximum fees and the aforementioned fee adjustment formula. This type of contract is expensive to administer and the contractor must have an adequate accounting system and should have an operating performance measurement and operating system. Cost data reporting is required so that the performance can be objectively measured. It is generally not used if contract definition has been accomplished.

- Cost Plus Fixed Fee (CPFF) - This type of contract is primarily used where the work is level of effort, exploratory research and development, with a defined goal, but without knowledge of the extent of the task. This contract is one of the least preferred forms as the contractor assumes no financial risk as they are paid their actual cost plus the fixed fee. It is in to forms, the "completion form" where the tasks can be defined and a definite goal or end product specified and in the "term form" where the scope of work can only be defined in general terms. The contractor is only liable for a stated level of effort for a specified period of time. It is frequently used for feasibility studies and initial exploration. It should not be used for major weapons system development.

- Letter Contract - This type of contract is to be used for national urgency type of work when it is required to start the contract immediately contract postponed until some later date. The Government liability amount is never more than 50% of the total estimated cost of the procurement. Additionally the contract contains a date by which the final contract will be negotiated. The letter contract is probably the least desirable from a Government point of view as the Government has maximum liability until definitized. Special permission must be obtained to use letter contracts and it must be determined that no other type is suitable. Actual cost data from an acceptable accounting system is required; however, there is much difficulty in obtaining cost performance data when this contract type is utilized as the contractor typically does not want to reveal all of his negotiation points.

- Cost and Cost Sharing (C/CS) - The cost contract is typically with non-profit organizations and universities. When cost sharing is the agreed form, then the joint sponsorship will enable a commercial contractor to facilitize his plant or be in the ground floor of new technology. No fee is paid on these contracts as the Government is only liable for costs in accordance with the cost accounting standards. Usually these contracts are of comparatively low value. They frequently are of the type of work where it is impossible to estimate a firm cost.

- Time and Materials (TM) Labor Hours (LH) - These contracts are as the name implies, time and material oriented. Work is not pre-specified, is on a "call" basis at a specified set of labor rates and includes (in the case of TM) material at cost. These contracts cannot be estimated except for each individual job and cost is not effective. They require constant Government monitoring to ensure effective management by the contractor.

- Indefinite Delivery - These contracts are for a definitive performance period but the exact delivery schedule is not known. They are in three types. Definitive Quantity - a quantity of a supply or service over the life of the contract. Requirements - this is to fulfill all Government requirements of supplies and services for the life of the contract. Each order has the funds obligated separately with a limit to the Government ordering obligation. Indefinite quantity- the contractor agrees to supply the specified supplies and services as requested with a minimum of delay at a pre-arranged price. The contract contains a minimum and maximum of quantity delivery to the end of each fiscal year. Funds may be allocated by each order and supplies or services are obtained as required. This is mainly used for commercial supplies or services as the need arises.

Contract Name: Production I	Report Period:1/28 - 2/24 1984					Negotiated Cost: $102.5M		
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$2,483	$2,487	$1,999	$4	$48	$4,769	$4,592	$177
Operations Labor	$4,112	$4,262	$3,494	$150	$764	$6,644	$5,851	$793
Field Labor	$58	$58	$33	$0	$25	$73	$48	$25
Non-Labor	$27,861	$32,187	$31,737	$4,326	$450	$48,316	$48,092	$224
Engineering Overhead	$3,948	$3,954	$3,020	$6	$934	$7,583	$6,515	$1,068
Operations Overhead	$6,537	$6,777	$6,015	$240	$762	$10,564	$10,093	$471
Field Overhead	$29	$29	$13	$0	$16	$36	$21	$15
Procurement Overhead	$1,280	$1,483	$1,394	$203	$89	$2,239	$2,060	$179
Division G and A	$4,651	$5,142	$5,417	$491	($275)	$8,099	$8,906	($807)
Corporate G and A	$1,559	$1,724	$1,478	$165	$246	$2,716	$2,364	$352
Cost of Money	$525	$581	$437	$56	$144	$910	$869	$41
Obsolete Materials	$0	$0	$0	$0	$0	$0	$250	($250)
Total	$53,043	$58,684	$55,037	$5,641	$3,647	$98,522	$94,427	$4,095

Contract Name: Production I		Report Period: 9/30 - 10/26 1984				Negotiated Cost: $102.5M		
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$3,966	$3,942	$3,362	($42)	$562	$6,056	$5,954	$102
Operations Labor	$5,909	$5,954	$4,591	$45	$1,363	$6,853	$5,376	$1,474
Field Labor	$67	$67	$41	$0	$26	$77	$51	$26
Non-Labor	$42,379	$43,615	$43,411	$1,236	$204	$52,108	$51,833	$275
Engineering Overhead	$6,229	$6,174	$4,798	($55)	$1,376	$9,391	$8,195	$1,196
Operations Overhead	$9,398	$9,470	$7,785	$72	$1,685	$10,903	$9,075	$1,828
Field Overhead	$33	$33	$16	$0	$17	$38	$21	$17
Procurement Overhead	$1,945	$2,011	$1,953	$66	$58	$2,336	$2,286	$50
Division G and A	$7,065	$7,196	$7,857	$131	($661)	$8,946	$10,046	$1,100
Corporate G and A	$2,358	$2,405	$21,159	$47	$246	$2,948	$2,758	$190
Cost of Money	$804	$817	$675	$13	$142	$1,048	$954	$94
Obsolete Materials	$0	$0	$0	$0	$0	$0	$250	($250)
Total	$80,153	$81,666	$76,648	$1,513	$5,018	$102,905	$98,035	$4,870

Contract Name: Production I		Report Period: 1/26 - 2/22 1985			Negotiated Cost: $102.5M			
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$4,822	$4,685	$4,105	($137)	$580	$6,125	$6,408	($283)
Operations Labor	$6,518	$6,491	$4,860	($27)	$1,631	$6,853	$5,289	$1,564
Field Labor	$73	$73	$45	$0	$28	$77	$45	$32
Non-Labor	$49,415	$48,287	$48,494	($1,128)	($207)	$52,224	$51,591	$633
Engineering Overhead	$7,533	$7,349	$5,763	($184)	$1,586	$9,485	$8,809	$676
Operations Overhead	$10,368	$10,325	$8,181	($43)	$2,144	$10,903	$8,855	$2,048
Field Overhead	$36	$36	$18	$0	$18	$38	$18	$20
Procurement Overhead	$2,255	$2,222	$2,216	($33)	$6	$2,339	$2,318	$21
Division G and A	$8,216	$8,039	$8,891	($177)	($852)	$8,973	$10,162	($1,189)
Corporate G and A	$2,729	$2,683	$2,432	($46)	$251	$2,955	$2,775	$180
Cost of Money	$944	$914	$766	($30)	$148	$1,053	$984	$69
Obsolete Materials	$0	$0	$0	$0	$0	$0	$250	($250)
Total	$92,909	$91,104	$85,771	($1,805)	$5,333	$102,899	$98,177	$4,722

Contract Name: Production I			Report Period: 9/28 - 10/25 1985			Negotiated Cost: $102.5M		
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$5,734	$5,543	$5,512	($191)	$31	$6,289	$6,885	($596)
Operations Labor	$6,829	$6,766	$5,082	($63)	$1,684	$6,854	$5,275	$1,579
Field Labor	$77	$77	$45	$0	$32	$77	$45	$32
Non-Labor	$51,637	$50,166	$49,861	($1,471)	$305	$52,657	$51,990	$667
Engineering Overhead	$8,906	$8,645	$7,536	($261)	$1,109	$9,747	$9,285	$462
Operations Overhead	$10,862	$10,763	$8,479	($99)	$2,284	$10,904	$8,774	$2,130
Field Overhead	$38	$38	$18	$0	$20	$38	$18	$20
Procurement Overhead	$2,325	$2,279	$2,283	($46)	($4)	$2,357	$2,369	($12)
Division G and A	$8,785	$8,546	$9,358	($239)	($812)	$9,056	$10,150	($1,094)
Corporate G and A	$2,902	$2,837	$2,618	($65)	$219	$2,983	$2,829	$154
Cost of Money	$1,024	$984	$786	($40)	$198	$1,062	$881	$181
Obsolete Materials	$0	$0	$0	$0	$0	$0	$250	($250)
Total	$99,119	$96,644	$91,578	($2,475)	$5,066	$102,607	$99,930	$2,677

Contract Name: Production I		Report Period: 9/27 - 10/31 1986				Negotiated Cost: $102.5M		
Item	Cumulative To Date					At Completion		
	Budgeted Cost		Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	Work Schedule	Work Performance						
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$6,222	$6,085	$7,019	($137)	($934)	$6,352	$7,530	($1,178)
Operations Labor	$6,892	$6,832	$5,127	($60)	$1,705	$6,899	$5,180	$1,719
Field Labor	$77	$77	$45	$0	$32	$77	$45	$32
Non-Labor	$52,681	$51,555	$51,364	($1,126)	$191	$52,695	$52,143	$552
Engineering Overhead	$9,634	$9,444	$9,518	($190)	($74)	$9,837	$10,173	($336)
Operations Overhead	$10,964	$10,868	$8,555	($96)	$2,313	$10,974	$8,630	$2,344
Field Overhead	$38	$38	$18	$0	$20	$38	$18	$20
Procurement Overhead	$2,355	$2,316	$2,345	($39)	($29)	$2,355	$2,383	($28)
Division G and A	$9,053	$8,870	$9,945	($183)	($1,075)	$9,088	$10,191	($1,103)
Corporate G and A	$2,981	$2,930	$2,781	($51)	$149	$2,993	$2,862	$131
Cost of Money	$1,062	$1,033	$863	($29)	$170	$1,066	$894	$172
Obsolete Material						$0	$50	($50)
Total	$101,959	$100,048	$97,580	($1,911)	$2,468	$102,554	$100,624	$1,930

Contract Name: Production I		Report Period: 2/28 - 3/27 1987			Negotiated Cost: $102.5M		
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$6,350	$6,266	$7,395	($84)	($1,129)	$6,352	$7,907	($1,555)
Operations Labor	$6,898	$6,872	$5,285	($26)	$1,587	$6,899	$5,207	$1,692
Field Labor	$77	$77	$45	$0	$32	$77	$45	$32
Non-Labor	$52,694	$52,163	$51,817	($531)	$346	$52,695	$52,289	$406
Engineering Overhead	$9,834	$9,715	$10,011	($119)	($296)	$9,837	$10,639	($802)
Operations Overhead	$10,973	$10,929	$8,782	($44)	$2,147	$10,974	$8,673	$2,301
Field Overhead	$38	$38	$18	$0	$20	$38	$18	$20
Procurement Overhead	$2,355	$2,338	$2,353	($17)	($15)	$2,355	$2,361	($6)
Division G and A	$9,088	$8,997	$10,131	($91)	($1,134)	$9,088	$10,268	($1,180)
Corporate G and A	$2,993	$2,968	$2,822	($25)	$146	$2,993	$2,864	$129
Cost of Money	$1,066	$1,052	$880	($14)	$172	$1,066	$900	$166
Obsolete Material						$0	$50	($50)
Total	$102,366	$101,415	$99,539	($951)	$1,876	$102,554	$101,549	$1,005

Contract Name: Production II			Report Period: 28 Jan - 24 Feb 1984			Negotiated Cost: $92.8M		
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$517	$513	$447	($4)	$66	$4,630	$4,638	($8)
Operations Labor	$871	$762	$780	($109)	($18)	$5,271	$5,264	$7
Field Labor	$6	$6	$2	$0	$4	$32	$28	$4
Non-Labor	$1,777	$1,195	$1,202	($582)	($7)	$42,426	$424,000	$26
Engineering Overhead	$786	$778	$656	($8)	$122	$7,038	$6,308	$730
Operations Overhead	$1,549	$1,356	$1,369	($193)	($13)	$9,383	$9,172	$256
Field Overhead	$3	$3	$0	$0	$3	$17	$15	$2
Procurement Overhead	$88	$58	$51	($30)	$7	$2,133	$1,758	$375
Division G and A	$621	$518	$532	($103)	($14)	$7,873	$8,206	($333)
Corporate G and A	$178	$148	$139	($30)	$9	$2,255	$2,090	$165
Cost of Money	$60	$50	$83	($10)	($33)	$762	$884	($122)
Obsolete Material	$0	$0	$0	$0	$0	$0	$300	($300)
Total	$6,456	$5,387	$5,261	($1,069)	$126	$84,750	$81,918	$2,832

Contract Name: Production II	Report Period: 30 Sept - 26 Oct 1984			Negotiated Cost: $92.8M				
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$1,226	$1,170	$936	($56)	$234	$4,639	$4,548	$91
Operations Labor	$1,964	$1,646	$1,628	($318)	$18	$5,274	$5,362	($88)
Field Labor	$16	$16	$6	$0	$10	$33	$20	$13
Non-Labor	$8,606	$6,540	$6,573	($2,066)	($33)	$42,128	$42,270	($142)
Engineering Overhead	$1,864	$1,779	$1,294	($85)	$485	$7,051	$5,964	$1,087
Operations Overhead	$3,496	$2,930	$2,743	($566)	$187	$9,388	$8,518	$870
Field Overhead	$8	$8	$2	$0	$6	$18	$10	$8
Procurement Overhead	$430	$325	$306	($105)	$19	$2,117	$1,922	$195
Division G and A	$1,955	$1,600	$1,712	($355)	($112)	$7,842	$8,211	($369)
Corporate G and A	$560	$459	$464	($101)	($5)	$2,246	$2,363	($117)
Cost of Money	$189	$154	$207	($35)	($53)	$758	$929	($171)
Obsolete Material	$0	$0	$0	$0	$0	$0	$300	($300)
Total	$20,314	$16,627	$15,871	($3,687)	$756	$85,072	$81,594	$3,478

Contract Name: Production II		Report Period: 26 Jan - 22 Feb 1985				Negotiated Cost: $92.8M		
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$1,649	$1,565	$1,237	($84)	$329	$4,668	$4,593	$75
Operations Labor	$2,626	$2,187	$2,188	($439)	($1)	$5,340	$5,229	$111
Field Labor	$19	$17	$6	($2)	$11	$33	$16	$17
Non-Labor	$13,798	$11,182	$11,124	($2,626)	$58	$42,130	$42,227	($97)
Engineering Overhead	$2,506	$2,379	$1,685	($127)	$694	$7,096	$6,128	$968
Operations Overhead	$4,674	$3,893	$3,613	($781)	$280	$9,506	$8,409	$1,097
Field Overhead	$11	$9	$2	($2)	$7	$18	$7	$11
Procurement Overhead	$691	$559	$533	($132)	$26	$2,117	$1,963	$154
Division G and A	$2,882	$2,419	$2,630	($463)	($211)	$7,871	$8,991	($1,120)
Corporate G and A	$826	$693	$710	($133)	($17)	$2,255	$2,425	($170)
Cost of Money	$280	$234	$305	($46)	($71)	$760	$823	($63)
Obsolete Material	$0	$0	$0	$0	$0	$0	$300	($300)
Total	$29,962	$25,137	$24,003	($4,825)	$1,104	$85,725	$82,745	$2,980

Contract Name: Production II		Report Period: 28 Sept - 25 Oct 1985				Negotiated Cost: $92.8M		
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$2,635	$2,577	$2,220	($58)	$357	$4,923	$4,798	$125
Operations Labor	$4,096	$3,819	$3,774	($277)	$45	$5,391	$5,028	$363
Field Labor	$27	$27	$6	$0	$21	$33	$5	$28
Non-Labor	$32,970	$29,044	$28,776	($3,926)	$268	$42,145	$41,966	$176
Engineering Overhead	$4,006	$3,917	$2,930	($89)	$987	$7,483	$6,212	$1,271
Operations Overhead	$7,291	$6,797	$5,983	($494)	$814	$9,595	$7,895	$1,700
Field Overhead	$15	$15	$2	$0	$13	$18	$3	$15
Procurement Overhead	$1,662	$1,463	$1,518	($199)	($55)	$2,116	$2,120	($4)
Division G and A	$5,850	$5,289	$5,961	($561)	($672)	$7,959	$8,755	($796)
Corporate G and A	$1,676	$1,515	$1,611	($161)	($96)	$2,281	$2,364	($83)
Cost of Money	$567	$512	$453	($55)	$59	$770	$721	$49
Obsolete Material	$0	$0	$0	$0	$0	$0	$300	($300)
Total	$60,795	$54,975	$53,234	($5,820)	$1,741	$89,841	$86,004	$3,837

Contract Name: Production II	Report Period: 1 Feb - 28 Feb 1986			Negotiated Cost: $92.8M				
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$3,246	$3,189	$2,709	($57)	$480	$4,924	$4,778	$146
Operations Labor	$4,712	$4,457	$4,371	($255)	$86	$5,472	$5,262	$210
Field Labor	$31	$31	$6	$0	$25	$33	$6	$27
Non-Labor	$39,155	$36,735	$36,823	($2,420)	($88)	$42,332	$42,279	$53
Engineering Overhead	$4,934	$4,847	$3,595	($87)	$503	$7,486	$6,283	$1,203
Operations Overhead	$8,387	$7,934	$6,973	($453)	$1,252	$9,740	$8,226	$1,404
Field Overhead	$17	$17	$2	$0	$961	$18	$3	$15
Procurement Overhead	$1,972	$1,849	$1,983	($123)	$15	$2,124	$2,243	($119)
Division G and A	$6,933	$6,556	$7,291	($377)	($134)	$8,003	$8,598	($595)
Corporate G and A	$1,986	$1,878	$1,893	($108)	($735)	$2,293	$2,299	($6)
Cost of Money	$671	$634	$537	($37)	($15)	$775	$739	$36
Obsolete Material	$0	$0	$0	$0	$97	$0	$300	($300)
Total	$72,044	$68,127	$66,183	($3,917)	$1,944	$89,831	$86,499	$3,332

Contract Name: Production II		Report Period: 31 Jan - 27 Feb 1987			Negotiated Cost: $92.8M		
Item	Budgeted Cost		Cumulative To Date			At Completion		
	Work Schedule	Work Performance	Actual Cost Work Performance	Variance		Budgeted	Latest Revised Estimate	Variance
	BCWS	BCWP	ACWP	Schedule	Cost			
Engineering Labor	$5,173	$5,144	$4,315	($29)	$829	$5,416	$4,679	$737
Operations Labor	$5,658	$5,651	$5,506	($7)	$145	$5,671	$5,607	$64
Field Labor	$33	$33	$6	$0	$27	$33	$6	$27
Non-Labor	$43,422	$43,311	$42,519	($111)	$792	$43,447	$42,861	$586
Engineering Overhead	$7,863	$7,819	$5,665	($44)	$2,154	$8,232	$6,111	$2,121
Operations Overhead	$10,072	$10,059	$8,681	($13)	$1,378	$10,094	$8,823	$1,271
Field Overhead	$18	$18	$3	$0	$15	$18	$3	$15
Procurement Overhead	$2,172	$2,167	$2,159	($5)	$8	$2,173	$2,168	$5
Division G and A	$8,244	$8,221	$8,598	($23)	($377)	$8,320	$8,732	($412)
Corporate G and A	$2,361	$2,355	$2,314	($6)	$41	$2,383	$2,355	$28
Cost of Money	$797	$796	$683	($1)	$113	$806	$706	$100
Obsolete Material	$0	$0	$0	$0	$97	$0	$300	($300)
Total	$85,813	$85,574	$80,449	($239)	$5,125	$89,816	$84,343	$5,473

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